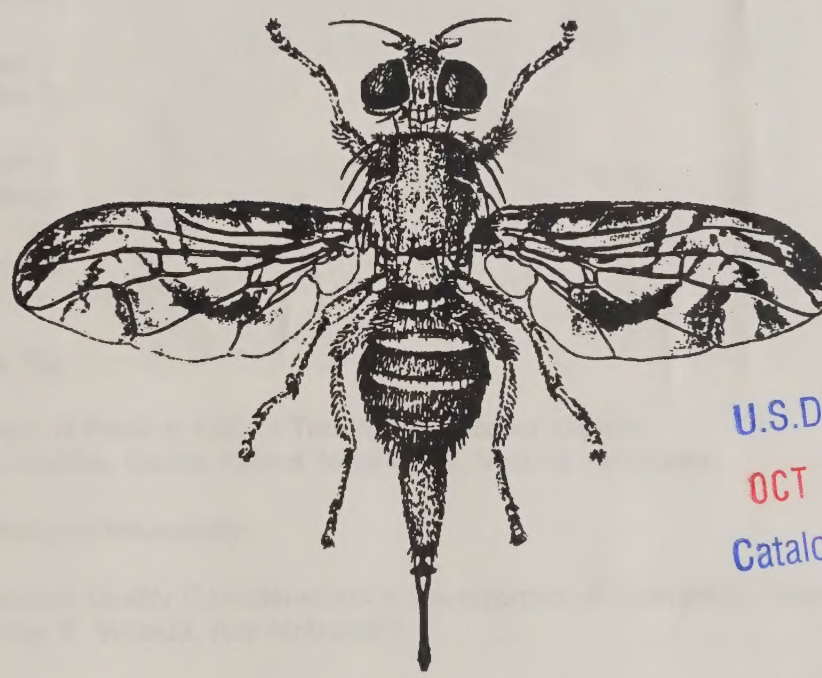
Quarantine Workshop for Horticultural Commodities

September 15-16, 1992
Fish Camp, California

FINAL REPORT



Agricultural Research Service

United States Department of Agriculture

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PREFACE

The Agricultural Research Service (ARS) Quarantine Workshop for Horticultural Commodities was held September 15-16, 1992 at Fish Camp, California. The major objectives of the workshop were to integrate the priorities of industry, the USDA Animal and Plant Health Inspection Service (APHIS) and the ARS. Other objectives were (1) define high priority research areas that can be addressed by ARS and (2) define methods to attain goals identified by various user groups. The National Program Staff of the ARS utilizes information provided by the participants to develop research projects and programs to ensure that research needs of industry, national, international, and state agencies are met. Specialists in the area of quarantine provided overviews on current research areas including objectives, constraints, time frames and needs.

Appreciation is extended to invited speakers. Special thanks are extended to Gordon L. Millard (ARS, Miami, Florida), Gina T. Miller and Libby N. Fouse (ARS, Fresno, California) for help with the workshop and for development of this document; Jennifer L. Sharp (ARS, Miami, Florida), Robert L. Mangan (ARS, Weslaco, Texas), Victoria Y. Yokoyama and Patrick V. Vail (ARS, Fresno, California) for organizing the workshop.

EXECUTIVE SUMMARY

The Agricultural Research Service (ARS) has been challenged to help facilitate state, national, and international movement of agricultural commodities. The need to provide commodities that are pest free and marketable is an ongoing challenge. ARS supports commodity quarantine research at laboratories in Miami, Florida; Weslaco, Texas; Fresno, California; Yakima, Washington; and Hilo, Hawaii. New and ongoing quarantine research programs all aimed at meeting consumer demands and industry needs. An overview of ARS-APHIS interactions included the general APHIS structures and programs involving ARS quarantine research support. Information was provided concerning the production and use of methyl bromide as well as research priorities for methods to replace the use of methyl bromide. Activities at the major ARS laboratories were reviewed. Approaches and methods for research and new results were presented from several programs. The movement of commodities must meet quarantine regulations enforced by APHIS. Commodities for export must meet quarantine requirements established by importing countries. Cooperation among ARS, state and federal quarantine agencies, and industry will help ensure that American agricultural exports will remain pest-free.

Communications among industry, ARS, APHIS, state and other concerned groups should be a major goal so that concerned groups **can create** mutually beneficial research projects and pest management practices. Information that impacts each group should be made available for the groups.

Methods to control methyl bromide emissions are needed so that the chemical may continue to be used for quarantine purposes. Alternative quarantine treatments must be developed that will serve as alternate treatments for methyl bromide fumigation. Use of systems approaches should be investigated fully. New statistical avenues could be studied and used in the systems approaches to ensure quarantine security. Generic quarantine treatments should be carefully evaluated for treatments as irradiation, heat, and cold for fruit flies. Research must define the causes of commodity damage resulting from quarantine treatments. Factors that could predispose **fruit to** commodity injury should be identified. Perhaps models could be developed that will help predict commodity damage.

PLENARY SESSION

Moderator: Dr. Victoria Y. Yokoyama, USDA, ARS, HCRL, Fresno, CA

Introductory comments were presented. Robert Reginato, USDA, ARS, Pacific West Area Director, Albany, CA. discussed the impact of the drought on California agriculture. Issues and problems regarding quarantine and commodity treatments were discussed in relation to demands of industry, the hard work and concerns of scientists, profitability, and ARS programs. The U.S. and other countries need to understand mutual concerns and cooperate to resolve problems. ARS should provide growers with crop diversification. Dr. Kenneth Vick, USDA, ARS, National Program Staff, Beltsville, MD. identified this meeting as the first to include regulatory, industry, state and research interests to discuss the current and future research needs in quarantine that may impact industries in the movement of commodities. Quarantine issues include the status of methyl bromide and its potential ban in 2000, foreign regulations, restrictions, and requirements, and the need for alternate treatments for new commodities and new pests. ARS must solve problems that arise and be prepared to deal with issues before they arise so that potential problems will be solved faster.

INDUSTRY INVOLVEMENT

SUMMARY

Moderator: Eric Jang
USDA-ARS, Hilo, HI

Some issues raised during the discussion session included:

Where does industry go with a quarantine related problem?

How can industry, ARS and APHIS work together to solve quarantine related problems?

Is there a standard operating procedure that is operational for APHIS, ARS and industry?

How do ARS and APHIS set their priorities regarding the research and development of quarantine treatments?

How can industry help to facilitate a more timely response to their needs in the quarantine area?

Is it possible for industry to attend meetings such as the bilateral quarantine meetings and other meetings between the U.S. government and other countries so that questions raised by other countries can be answered to the country's satisfaction?

How are ARS, APHIS and industry approaching the possible loss of methyl bromide?

Participants from State Departments of Agriculture (Texas and Florida) shared their thoughts on how better facilitation could be achieved. This included the setting up of technical committees that included representatives of industry, ARS and APHIS to discuss regional projects and facilitate the prioritization process. Several states have successfully used the technical committee route to solve pressing agricultural problems in their state.

The discussion session concluded with a short list of recommendations regarding how to better facilitate cooperation between industry, ARS and APHIS. The number one suggestion was that all agencies open up channels of communication regarding issues, research, questions and alternatives which are being worked on by all of the interested parties. The industry representatives felt that good communication is a primary key to improving relationships in these areas. The second recommendation is that both the industry, APHIS and ARS set up better defined priorities so that industry will know where they stand.

It was agreed that there is a growing list of issues that no one can answer. These issues should continue to be discussed at future meetings of this type.

RECOMMENDATIONS: INDUSTRY INVOLVEMENT

1. Better communication among groups involved with quarantine issues.

2. Prioritize of projects that mutually affect industry, APHIS and ARS.

3. CO-involve of industry in import and export quarantine issues affecting their respective industries.

4. Develop of quarantine workplans for specific commodities

5. Develop alternatives to methyl bromide as quarantine treatments

INDUSTRY PERSPECTIVES

Mexico's Stonefruit Workplan Development

David W. Miller, Director, Export Market Development
California Tree Fruit Agreement

Horticultural commodity exports have expanded dramatically in the past decade to now rank as the top component in the agriculture segment of the U.S. balance of trade. California leads the U.S. in both production and export volume of horticultural commodities be they fresh or processed. Because of this there is great concern in California, among various commodity groups, with recent activities which negatively impact the continued potential for growth of exports. The specific situation to be discussed is the effect that recently completed, or are they still ongoing, technical negotiations had on the once significant trade of U.S. stonefruit to Mexico. What is understood, and appreciated, is that the effort was conducted to mitigate the effects of a particular foreign government's protectionist measure to stave off a U.S. agricultural pest. The concern is not that an "APHIS" is doing this. The concern is that *only* APHIS is doing this. There needs to be control and involvement from the full gambit of players in the game: from the community of science, ARS; the technocrats who manipulate the science, APHIS; the acting arms of the politicals, USTR and FAS; and especially from those that may live or die as a consequence of those actions, INDUSTRY.

The Agricultural Research Service should be aware that past research is being used as a boilerplate for solving phytosanitary conditions which it was not designed to solve. It is paramount that this only be done with input from ARS since the credibility of ARS research will become suspect if it is inappropriately applied and then found to be ineffective. ARS research has served the U.S. and international industry very well over the years and the maintenance of its integrity is entirely critical to the interest of the U.S. agricultural import/export complex.

In this particular case, using research developed for a quarantine program for preventing oriental fruit moth (OFM) in stone fruit from entry into British Colombia could probably be used as a model for developing a comparable approach in Mexico. But, the problem was, this research was used without either a full understanding or proper definition of how it was to be used. Nor was the affected industry adequately involved in the development of the negotiated quarantine settlement. This was not only inappropriate use of a quarantine solution, it was also untenable to the industry. There should have been a coordinated effort from the U.S. agencies as a whole so that we would not have been picked apart by an inexperienced foreign inspection agency that was merely looking to horse-trade the U.S. ban on Mexican avocados for the Mexico ban on U.S. stonefruit. We may have written the book on import

prevention, but they have mastered the game.

The California Tree Fruit Agreement (CTFA) is the promotional arm of California's fresh peach, nectarine, plum, and Bartlett pear industries. Besides promotion, they fund myriad research projects including those for export. They have long funded the ARS in projects that address markets such as Japan, Canada, and New Zealand. Because they have years of export development and research experience, it was distressing to find that negotiations with Mexico were not being conducted through the normal channels of communication.

Because CTFA, as a Market Promotion Program cooperator, is required to develop ties with the FAS offices globally, they will always work with that office regarding concerns of that particular country. In the case of Mexico, suddenly the FAS office was "out of the loop." To make matters worse, the APHIS regional office in Mexico was unable to comment on the negotiations because they were not directly involved either. To further frustrate the issue, CTFA, FAS and APHIS (the regional office) had just settled a licensing dispute with Mexico in 1991 and stone fruit trade had, for the first time, been open that year. Because none of the groups which had worked on that issue in 1991 were involved with the 1992 issue, there was limited experience at the table. This probably gave the Mexican negotiators the upper hand. Also, the new negotiators were negotiating under a new format, NAFTA, while the previous negotiations were related to the GATT rules of trade.

It is the industry's understanding that trade issues are to be worked on by the U.S. post in that particular country. Under the NAFTA this all seems to have changed, though not for the better. There is benefit to having the posted diplomats and technocrats deal with specific country issues. It did not seem appropriate that the Washington, D.C., or Hyattsville staff should be the negotiating team. And if that is to be the case, then inform those whom they (negotiating team) will impact. In this case, the industry lost access to a $7.0 million market that had just been expanded the prior year. And the industry also lost the benefit that Foreign Agriculture Service and Regional Director's office of APHIS had for many years provided.

American Hay Industry and International Plant Quarantine Issues

Ron T. Anderson, Co-Chairman
National Hay Association Export Committee

Approximately 150 million tons of hay are produced in the U.S. per year and exports compose approximately 1,700,000 tons of the annual production. Japan is the primary purchaser of U.S. hay. In 1983 Japan imported 81,444 metric tons of baled hay, 369,308 metric tons of cubes, which comprised 90% of the total Japan import market. In 1991 Japan imported 905,725 metric tons of bales, 553,853 tons of cubes, which composed 83% of the total Japan import market.

Exports strengthen the price that Western farmers receive for hay. My experience in exports began in 1971 when I shipped the first shipment of baled timothy hay to Japan. The Japanese imported timothy, a U.S. native grass, for race horses, then later imported timothy for for dairy and beef production. U.S. exports of baled hay to Japan quickly rose to 25,000 metric tons by 1975. In 1975 the Japan Plant Protection and Quarantine agency began rejecting hay from the U.S. based on a regulation that any product containing straw, wheat, barley or *Agropyron* sp. grasses were not allowed into the country because they are known to be hosts to the Hessian fly. Japan banned all shipments of timothy hay by 1976 because of the large number of rejections.

USDA, ARS, scientists developed a USDA certified fumigation quarantine treatment for standard bale timothy hay. The USDA, Foreign Agriculture Service and Animal and Plant Health Inspection Service and the Japan PPQ approved the program in 1979 which re-opened a very large market.

The USDA, ARS, is currently developing a similar quarantine treatment for six species of compressed hay. Cooperation throughout all USDA agencies has been successful and the hay industry has benefited by new and expanded markets. I encourage cooperative work and communication among foreign and USDA agencies with industry and urge industry to become involved in the team effort by investing their resources.

STATISTICAL APPROACHES

Moderator: Victor Chew, USDA-ARS, Gainesville, FL

Statistics in Quarantine Treatments

Bruce Mackey, USDA-ARS, WRRC, Albany, CA

PROBIT 9

Tolerance distribution - The probability of observing a response (kill) on an individual insect is equivalent to the probability that the insect's tolerance is less than a given dose. We observe proportions killed of a number of insects at each of a series of dose levels. These responses generally fall on an S-shaped curve with lower and upper limits of 0 and 100%, respectively. The probit method is one way of modeling the tolerance distribution and provides a linearization. The inverse of the cumulative normal distribution with the addition of five gives probits. (Five is added so that probits are positive for all practical purposes.)

The adoption of the probit 9 security level is attributed to Baker (1939). A probit value of 9 is equivalent to a response of 99.9968% mortality. The adoption of this particular level seems to have no other basis than to provide an extreme measure of control.

Statistical problems - Figure 1 shows an example out of Finney (1971) with both probit and logit fits to the data. As is often the case, doses were transformed by logs to fit the symmetrical tolerance distributions. (Note the characteristic asymmetrical S-shape of the curves in figure 1 which is indicative of the need for the log transformation of dose.) This is used as a "good" example in that the lack-of-fit tests are not significant ($p \sim 0.6$). The problem is in estimating a dose corresponding to the probit 9 response, which is an extrapolation way outside the range of the data, and lies far out on the upper tail of the S curve. Figures 2 and 3 show estimated doses and confidence intervals for responses up to the probit 9 extreme. (Note that for illustration purposes it is not an equal interval scale above 90%.) These two methods both work well and give almost identical estimates within the range of the data. Not only do the confidence intervals blow up at the probit 9 level, but the two methods give markedly different dose estimates:

Method	Dose	95% Confidence Limits	
Probit	43.1	28.9,	80.3
Logit	136.0	70.5,	400.0

(In addition to being outside the range of the data, the weighting factor also contributes to the wide confidence bands in the tails. The weighting factor for the probit analysis is Z^2n/PQ, where Z is the height of the standard normal density curve.) In reality, these methods were devised to estimate the LD50, and typical bioassays actually provide very little information about the probit 9.

Practical problems - We have an arbitrary criterion that is extremely costly to achieve. The first requirement is a rigorous bioassay. Verification requires over 30,000 insects, with 75,000 to 100,000 needed to attach any level of confidence to the results. Phytotoxicity and environmental concerns (residues) can be extremely important costs. Since there is wide variability in incidence levels for various pests and commodities, the question has been raised whether or not security level should depend in some way on incidence. It also seems reasonable to adjust security levels according to the severity of the consequences of a given pest.

Time Mortality - Time mortality assays sometimes involve repeated measures on the same batch of insects. This results in a variation from the standard probit analysis (Lampkin and Ogawa 1976). This design should be avoided if possible, i.e. independent batches of insects should be used for each time level. Note that probit analyses with time as the independent variable usually do not require the log transformation.

Alternative Approach to Probit 9

This approach will be detailed in Vail et al. (1993).

Infestation rate and natural survival - These parameters need to be estimated with some degree of confidence. We have been using 98.5% upper limits on these parameters and a 98.5% lower limit on treatment mortality to provide overall 95% confidence, i.e. $(0.985)^3$ is approximately 0.95, (Couey and Chew 1986). Using confidence limits in this fashion not only builds in a safety factor, but provides incentive for using large numbers of insects to estimate these parameters in order to achieve narrow confidence bands. Example 1 illustrates a method for obtaining exact confidence intervals for the binomial based on Zar (1984), and provides a listing of the SAS program (SAS Institute, 1988).

Required mortality - The required mortality is determined based on the concept of Landolt et al (1984), which demands a small probability that a mating pair occur together at a shipment destination. Their equation (4) is as follows:

$$P=\sum_{x=2}^{\infty}\left(\frac{e^{-NR}(NR)^{x}}{x!}\right)(1-0.5^{(x-1)})$$

where: x = number of flies in the shipment
N = number of fruit in the shipment
R = infestation rate (average number of larvae per fruit)

The first part uses the Poisson distribution to calculate the probability of any given number of flies being in the shipment. The second part gives the probability that the flies are not all of one sex, assuming both sexes are equally likely. Summation starts at two since at least two larvae are required to have both sexes. Chew later recognized this as a convergent, infinite series and simplified the equation to:

$$P=(1-e^{-NR/2})^{2}$$

this can be solved for NR as follows:

$$NR=-2\log_{e}(1-\sqrt{P})$$

The approach is to set the probability of obtaining a mating pair(P) at some small level and compute the required NR. Note that NR is the total larvae allowed in a shipment or at a receiving location. For P = 0.05, NR, 0.5062 and for P = 0.01, NR =0.2107. The treatment mortality required to achieve NR can be calculated from:

m = 1 - (NR/(i*s*n)) (Equation 1)

where i = infestation rate (98.5% upper limit)
s = natural survival (98.5% upper limit)
n = number of fruit in the shipment (Although N and n are equivalent, they are treated differently for computational purposes, i.e. NR is treated as a constant and n is varied to achieve the desired P.)

The equation for m is derived from the relationship, NR = i*s*n(1-m), solved for m, i.e. R = i*s(1-m). After obtaining m from the above equation, the treatment level should be set to achieve a 98.5% lower limit equal to this m. This

approach accomplishes two stated objectives: (1)The required mortality or treatment severity is a function of the infestation level. (2) The security level can be adjusted for the seriousness of the pest by changing P. (Note that n can also be reduced to achieve a smaller NR. In the paper by Vail et al. (1993) a series of tables were developed that give m for various infestation and natural survival rates and numbers of fruit.

Number of larvae required for treatment verification - If 100% mortality is obtained from treating n_m larvae, the lower 98.5% confidence limit using the binomial distribution can be calculated as:

$$e^{\log(0.015)/n_m}$$

recall from above that m is set equal to this quantity, then solving for n_m, gives:

$$n_m = \frac{\log(0.015)}{\log(m)}$$

Thus we have a means of calculating the number of larvae that must be treated with 100% mortality to achieve the m obtained in(*).

Further work - The paper by Baker et al (1990) uses a similar approach, but goes into more detail on the distribution of pests as fruit arrives at its destination. They propose sampling at the receiving end of the shipment, and give a method for determining minimum sample sizes required for specified confidence that the "Maximum Pest Limit" (MPL) has been achieved.

Analysis of Variance Models

Design - Since there will be biological variability in both the commodity and the pest, replication in the form of random samples is required. In some cases split plot designs are used inadvertently. The distinguishing feature of such designs is two or more sizes of experimental units. An example is a controlled atmosphere (CA) study which employs temperature chambers and vials within temperature chambers with the different CA treatments. The two experimental units are the temperature chamber and the vial within the temperature chamber. The important thing is that there will be two error terms, adding complexity to the statistical analysis.

Transformations - The most commonly used transformations are logits and arcsine square roots. We are striving for two things, linearity and homogeneity of variance. It is essential to plot the data and residuals to check for these properties. It is often necessary to remove data that is either all zeros or all 100% responses. For estimation of treatment means, estimates and confidence intervals are obtained in the transformed scale, then transformed back to percentages for final presentation.

Dose estimation - Treatment comparisons are often based on LD50's or LD95's and their confidence intervals. Example 2 shows how this can be done in conjunction with the SAS GLM procedure (SAS Institute. 1987), and includes a listing of a SAS IML program (SAS Institute. 1985) based on Zerbe (1978).

Figure 1.

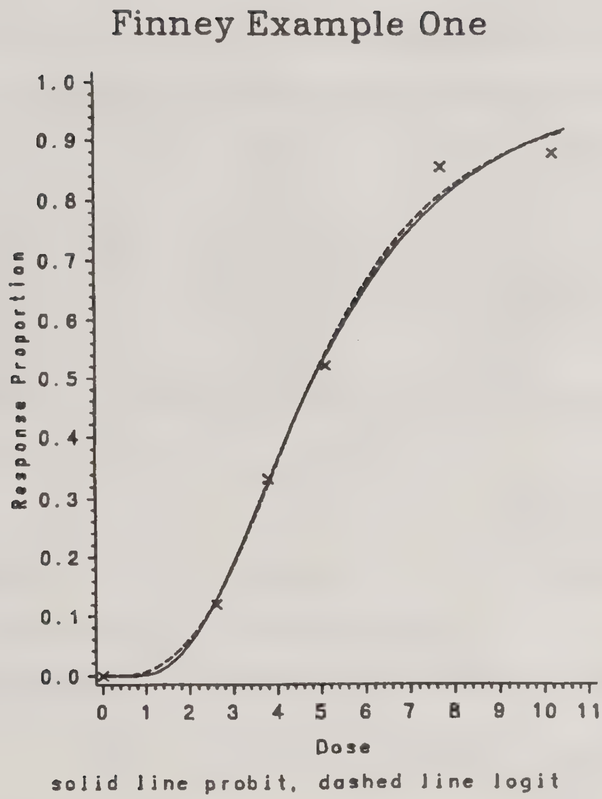


Figure 2.

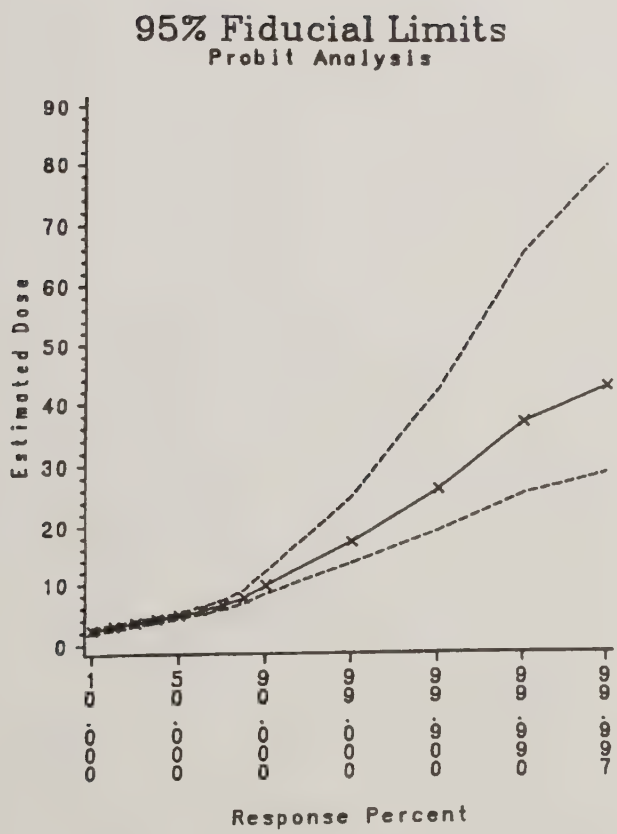
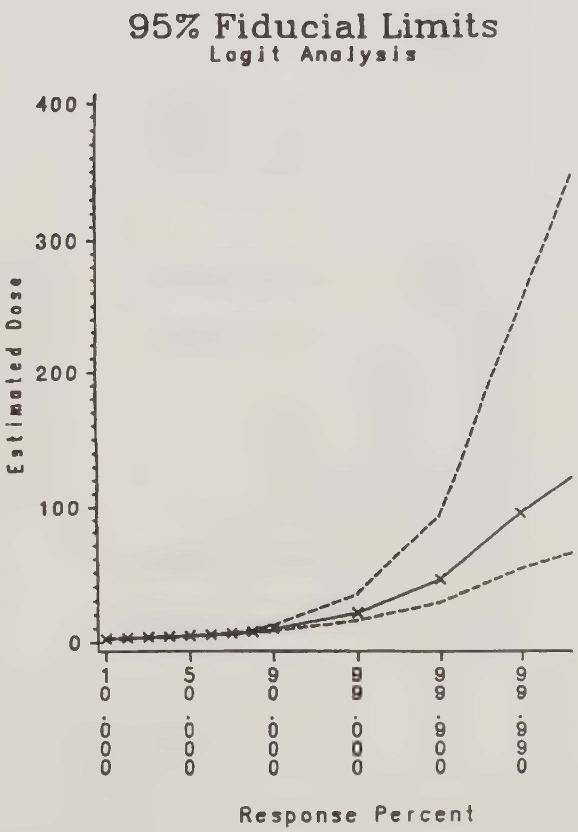


Figure 3.



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*Example One - SAS Source Code;

*Macro for Exact Confidence Interval for Binomial;
%macro cibin;
if x=0 then go to x0;
if x=n then go to xn;
v1=2*(n-x+1);
v2=2*x;
gamma=1-(alpha/2);
ll=x/(x+(n-x+1 )*finv(gamma,v1,v2,O));
phat=x/n;
v11=v2+2;
v22=v1-2;
ul=((x+1)*finv(gamma,v11,v22,0))/(n-x+(x+1)*finv(gamma,v11,v22,0));
go to end;
x0:ll=0;phat=0;
ul=1-exp(log(alpha)/n);
go to end;
xn:ul=1;phat=1;
ll=exp(log(alpha)/n);
end:
%mend;
options ps=54;
title '98.5%, One-tailed Confidence Limit for Binomial';
data a;
input n x;
alpha=.03; *puts .015 probability in each tail;
%cibin; *invokes macro;
cards;
5259 24
21976 111
1300 16
4000 1
5000 8
33000 47
712900 50
467500 95
proc print;
var n x phat ul alpha;
proc means sum noprint;
var n x;
output sum=n x;
data b; set;
alpha=.03;
%cibin; *invokes macro;
proc print;
var n x phat ul alpha;
data c; set a;
if _n_<=6;
proc means sum noprint;
var n x;
output sum=n x;
data b; set;
alpha=.03;
%cibin; *invokes macro;
proc print;
var n x phat ul alpha;
run;
```

Example One - SAS Output

98.5%, One-tailed Confidence Limit for Binomial 1

OBS	N	X	PHAT	UL	ALPHA
1	5259	24	0.004564	0.007037	0.03
2	21976	111	0.005051	0.006194	0.03
3	1300	16	0.012308	0.020791	0.03
4	4000	1	0.000250	0.001541	0.03
5	5000	8	0.001600	0.003335	0.03
6	33000	47	0.001424	0.001946	0.03
7	712900	50	0.000070	0.000095	0.03
8	467500	95	0.000203	0.000253	0.03

98.5%, One-tailed Confidence Limit for Binomial 2

OBS	N	X	PHAT	UL	ALPHA
1	1250935	352	.00028139	.00031576	0.03

98.5%, One-tailed Confidence Limit for Binomial 3

OBS	N	X	PHAT	UL	ALPHA
1	70535	207	.0029347	.0034092	0.03

Example Two - Data from GLM Procedure

Linear Regression Fitting Reps on Logit Responses

OBS	REP	DAYS	LOGIT2
1	1	6	.
2	1	8	.
3	1	10	.
4	1	12	.
5	1	14	1.54258
6	2	6	-0.29956
7	2	8	0.50236
8	2	10	0.58556
9	2	12	1.47791
10	2	14	1.87822
11	3	6	-0.17260
12	3	8	0.07309
13	3	10	1.03324
14	3	12	0.50045
15	3	14	1.42435
16	4	6	-0.25662
17	4	8	1.00444
18	4	10	1.40364
19	4	12	1.32960
20	4	14	1.64516
21	5	6	-0.42100
22	5	8	-0.14639
23	5	10	0.47347
24	5	12	1.30563
25	5	14	1.41989

Example Two - SAS Output From GLM Procedure

Linear Regression Fitting Reps on Logit Responses
General Linear Models Procedure
Class Level Information

Class	Levels	Values
REP	5	1 2 3 4 5

Number of observations in data set = 25

X'X Generalized Inverse (g2)

	INTERCEPT	REP 1	REP 2	REP 3
INTERCEPT	0.825	0.05	-0.2	-0.2
REP 1	0.05	1.3	0.2	0.2
REP 2	-0.2	0.2	0.4	0.2
REP 3	-0.2	0.2	0.2	0.4
REP 4	-0.2	0.2	0.2	0.2
REP 5	0	0	0	0
DAYS	-0.0625	-0.025	-1.77107E-17	-1.77107E-17
LOGIT2	-1.750542725	0.1055192507	0.3025805455	0.0453884461

	REP 4	REP 5	DAYS	LOGIT2
INTERCEPT	-0.2	0	-0.0625	-1.750542725
REP 1	0.2	0	-0.025	0.1055192507
REP 2	0.2	0	-1.77107E-17	0.3025805455
REP 3	0.2	0	-1.77107E-17	0.045388446i
REP 4	0.4	0	-1.77107E-17	0.4989258004
REP 5	0	0	0	0
DAYS	-1.77107E-17	0	0.00625	0.2276861083
LOGIT2	0.4989258004	0	0.2276861083	1.43695443

Example Two - SAS Output from GLM Procedure

Linear Regression Fitting Reps on Logit Responses

General Linear Models Procedure

Dependent Variable: LOGIT2

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	9.72718751	1.94543750	20.31	0.0001
Error	15	1.43695443	0.09579696		
Corrected Total	20	11.16414194			

R-Square	C.V.	Root MSE	LOGIT2 Mean
0.871288	39.86726	0.30451	0.77635

Source	DF	Type X SS	Mean Square	F value	Pr > F
REP	4	1.43263329	0.35815832	3.74	0.0265
DAYS	1	8.29455423	8.29455423	86.58	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	4	0.82597993	0.20649498	2.16	0.1240
DAYS	1	8.29455423	8.29455423	86.58	0.0001

Parameter		Estimate	T for HO: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		-1.750542725 B	-6.23	0.0001	0.28112718
REP	1	0.105519251 B	0.30	0.7690	0.35289666
	2	0.302580545 B	1.55	0.1430	0.19575184
	3	0.045388446 B	0.23	0.8198	0.19575184
	4	0.498925800 B	2.55	0.0223	0.19575184
	5	0.000000000 B	.	.	.
DAYS		0.227686108	9.31	0.0001	0.02446898

NOTE: The X'X matrix has been found to be singular and a generalized inverse was used to solve the normal equations. Estimates followed by the letter 'B' are biased, and are not unique estimators of the parameters.

LT95 = 19.78 with 95% confidence interval (17.97, 22.59)

```
*Example Two - SAS Source Code;
*Linear calibration;
*model: lin. regr. w. 5 reps.;
DATA SEG1;
INPUT ROW$ 1-9 COL1-COL5;
CARDS;
INTERCEPT    0.825   0.05    -0.2    -0.2    -0.2
REP 1         0.05   1.3      0.2     0.2     0.2
REP 2        -0.2    0.2      0.4     0.2     0.2
REP 3        -0.2    0.2      0.2     0.4     0.2
REP 4        -0.2    0.2      0.2     0.2     0.4
REP 5         0      0        0       0       0
DAYS         -0.0625 -0.025 -1.72085E-17 -1.72085E-17 -1.72085E-17
LOGIT2       -1.750542725 .10551925073 .30258054546 .04538844608 .49892580042
DATA SEG2;
INPUT ROW$ 1-9 COL6-COL8;
CARDS ;
INTERCEPT       0    -0.0625 -1.750542725
REP 1           0    -0.025 .10551925073
REP 2           0 -1.72085E-17 .30258054546
REP 3           0 -1.72085E-17 .04538844608
REP 4           0 -1.72085E-17 .49892580042
REP 5           0 0 0
DAYS            0 0.00625 0.2276861083
LOGIT2          0 0.2276861083  1.43695443
DATA INVERSE;
MERGE SEG1 SEG2;
IF ROW='LOGIT2' THEN DELETE;
DROP ROW COL8;
PROC IML;
START;
/*
Zerbe, Gary
"On Fieller's theorem and the general linear model"
Am. Stat. 32: 103-106
August, 1978
*/
A=(L`*B)**2-T*(L`*I*L)*S;
B1=2*(T*(K`*I*L)*S-(K`*B)*(L`*B));
C=(K`*B)**2-T*(K`*I*K)*S;
R=(K`*B)/(L`*B);
LL=(-B1-(B1**2-(0*A*C))##.5)/(2*A);
UL=(-B1+(B1**2-(0*A*C))##.5)/(2*A);
PRINT R LL UL;
FINISH;
L={0,0,0,0,0,0,1};
K={-1,-.2,-.2,-.2,-.2,-.2,0};
B={-4.6949,.1055,.3026,.0454,.4989,0,.2277}; *-4.6949 = intercept-y;
USE INVERSE;                                 *where R=x(est.):y;
READ ALL INTO I;                             *LT95: y=log(.95/.05)=2.9444;
T=4.54;                                      *Student's t squared;
S=.09579696;                                 *error mean square;
RUN ; QUIT;
run;
```

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STATISTICAL CONSIDERATIONS

Moderator: Victor Chew, USDA-ARS, Gainsville, FL

1. In calculating the number N of organisms that must be tested such that if s survivors are found (s = 0 is the most common case), we have a prescribed assurance (e.g., 95% probability, say) that the unknown true mortality rate is at least R (e.g., R = 99.9968, say), as discussed in Couey and Chew (1986), J. Econ. Entomol. 79: 887-890. It is assumed that the N organisms are tested in one session. In practice, n_i are tested in the i^{th} experiment (i = 1, 2, ..., r). If zero survivors are found in the r experiments, what is the 95% lower confidence limit for the unknown mortality rate?

2. In a dose-mortality study, there may be r replicates, with n_{ij} organisms treated at dose x_i in the j^{th} replicate (j = 1,2, ..., r; i = 1, ..., d, the number of doses). SAS treats these r experiments as a single experiment, by summing over the reps the number tested and the number that died at each dose. Can this be improved?

3. In a dose mortality study, the number of organisms treated at each dose is often unknown, and is estimated from an independent sample of untreated fruits from which the larvae are allowed to emerge. The number treated at a dose should be regarded as a random variable rather than a known constant.

4. Whether the distribution of the insect tolerances is assumed to be normal, logistic, or Gompertz (leading to the probit, logit, and log-log transforms of percent mortality, respectively), it is further assumed that the individual larvae act independently. While larvae in different fruits may reasonably be taken to be independent, larvae within the same fruit will likely be correlated in their response to the stimulus. This correlation is ignored in the analysis. Some work has been done in this area (e.g., Preisler, H.K., Assessing insecticide bioassay date with bioassay data with extra-binomial variation, J, Econ. Entomol. 81 (1988), 759-765; Boos, D.D., Analysis of dose-response data in the presence of extrabinomial variation, J. Royal Stat. Soc. 42 (1993), 173-183; etc.)

5. In cases of a poor fit, SAS multiplies the variances and covariances of the estimates by a "heterogeneity factor" (the goodness-of-fit chi-square statistic divided by its degrees of freedom), and uses the Student's t-distribution instead of the normal distribution in calculating the fiducial limits. This method is only valid if the numbers tested at each dose are the same. D. Collett, Modeling Binary Data, Chapman & Hall, New York, 1991, page 188-192, discusses four other alternative methods for handling lack-of-fit.

Research Priorities

1. Quarantine security based on probit 9 mortality should be tempered by a thorough knowledge of the biology and host relations of the subject species.

2. Derive tables of sample sizes and confidence intervals for risk of introductions when insects are known to have distributions that are more clumped than the poisson distribution. fore example if the K (from the negative binomial distribution) is known from field sampling, what percent survival should be tolerated from a treament to achieve a maximum risk of male and female introductions? Presumeably a higher K (less clustering) calculated from field samples should result in a less stringent treatment.

ARS, APHIS, AND OTHER AGENCY INTERACTIONS

PART I

OVERVIEW

Moderator: Norman C. Leppla

USDA, APHIS, Plant Protection and Quarantine,
Methods Development

The Animal and Plant Health Inspection service (APHIS) of the United States Department of Agriculture (USDA) is required by law to conduct the agricultural quarantine inspection (AQI) program for the nation. This authority is contained in the Plant Quarantine Act, 1912; the Honey Bee Act, 1922; the Tariff Act,1930; the Mexican Border Act, 1942; the Organic Act, 1944; the Golden Nematode Act, 1948; the Federal Plant Pest Act, 1957; the Federal Noxious Weed Act, 1974; and related legislation and regulations. The purpose of the AQI program is to protect United States agriculture from potentially harmful pests, diseases, and weeds that are foreign or of limited distribution in the country (Fuell, 1982). This is accomplished by inspecting agricultural products at ports of entry to ensure that they are pest- and disease-free, requiring that they be treated to eliminate contaminants, or excluding them from entering. In the event that foreign pests and diseases are introduced inadvertently, every effort is made to detect, contain, and eradicate them before they become widely distributed (Klassan 1989).

The Agricultural Research Service (ARS) supports the APHIS, AQI program by developing quarantine treatment schedules, providing pertinent research data, and technically certifying that a proposed quarantine treatment schedule will provide quarantine security (Army 1985, Ouye 1985, Plowman and Glosser 1991). With technical guidance from ARS, APHIS is responsible for coordinating the application of research findings in a manner which results in an effective commodity certification system (Helms 1985). In practice, ARS and APHIS cooperate closely to ensure that new procedures are adequately tested and found to be operationally feasible (Bare 1992). This usually involves some kind of pilot testing, during which intentions are published in the Federal Register and potential problems are identified before the APHIS, Plant Protection and Quarantine (PPQ) Treatment Manual is revised and final rules are implemented. Routine inspection thereafter provides feedback as to the efficacy of the practices.

Industry and the USDA, ARS and APHIS, have the common commitment of optimizing the movement of clean agricultural commodities from production

areas to global markets (Thomas et al. 1990). Regulatory constraints enforced by APHIS result in technological needs that industry communicates primarily to ARS and secondarily to industrial research and development. This ultimately produces new technologies that industry, with APHIS assistance, adapts to specific commodities and locations. A three-way partnership is thus formed to identify, research, field-test, and deliver new options for providing clean commodities. These options include elimination of the need for treatment or treatment by the least invasive methods:

<u>Eliminate the Need for Treatment</u>

- Ensure infestation- and infection-free crops
- Eradicate key pests at the origins of the crops
- Develop host resistance
- Employ systematic risk assessment

<u>Require Treatment</u>

- Perform chemical fumigation
- Manipulate temperature
- Develop irradiation
- Employ physical barriers

Exotic arthropod pests clearly cause a disproportionate amount of damage to American agriculture, as compared to native species (Sailer 1983). Only about 1% of the total arthropod fauna, 1,600 species, is of foreign origin. Yet, of the estimated 600 species of insects and mites that require control in the United States every year, about 235 are immigrants (Schwartz and Klassan 1981). Moreover, it has been estimated that about 50% of the major arthropod pests in the United States are non-indigenous (Klassan 1989). Existing regulatory practices, therefore may not be consistent with agricultural systems and biological realities (Husnik 1985).

APHIS is not only responsible for excluding or rapidly eliminating exotic agricultural pests and diseases but it must accomplish this charge with minimal cost, environmental impact, and disruption of trade. For this reason, the agency sponsored a thorough analysis of their AQI program that resulted in the following recommendations for increased research (Eden et al.1985):

- Provide adequate funding and other resources for research relating to AQI programs, at the Department of Agriculture level.

- Increase research on the biology, systematics, and taxonomy of potentially high risk exotic pests and diseases.

- Determine the origins and population structures of new infestations of foreign pests and pathogens.

- Develop more definitive data for predicting the economic impacts of foreign pests that could become established in the U.S.

- Determine the conditions and thresholds for exotic pest establishment.

- Develop new and improved technology for detecting and eradicating immigrant pests.

- Identify pest pathways and develop capabilities for their interdiction.

- Investigate the use of expert systems or models to proportion inspection resources relative to risk and to predict the impact of new exotic pests.

- Re-establish the APHIS/ARS committee for improving AQI research and application.

- Develop new pesticides, pesticide formulations, and other disinfestation/disinfection procedures for agricultural commodities, particularly replacements for chemicals such as methyl bromide.

- Develop the capability of eradicating foreign and domestic sources of pest populations.

- Investigate biological control as a means of reducing foreign sources of exotic pests and diseases (added).

- Explore applications of biotechnology to AQI problems, i.e., ripening genes (added).

- Research chemically-induced and genetically selected plant and animal resistance (added).

- Advance the scientific and philosophical basis of pest exclusion, i.e., garner national and international scientific and technical support, maintain current knowledge bases, and improve communication and collaboration (added).

APHIS encourages ARS and other research institutions to develop alternative, non-chemical processes to replace chemical treatments (Wood 1992). If Environmental Protection Agency (EPA) registrations were canceled for chemicals currently in use or if EPA Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) Section 18 (emergency) exemptions were revoked, it

would be debilitating to the agency. Routine fumigation of products to eliminate undetected pests, such as cotton seed for pink bollworm, chestnuts for weevils and other beetles, cut flowers for *Thrips palmi*, and packing materials for khapra beetle should be supplanted by environmentally benign methods. These kinds of new technologies are adapted from research to operational use by APHIS methods Development (Leppla and Schwalbe 1990). The following preliminary list of methods development activities is complimentary with the research recommendations, although some of the more routine activities could be accomplished by support staffs:

- Foster and adapt new inspection, detection, treatment and control technologies from research and improve existing capabilities for operational AQI, i.e., x-ray inspection of baggage, screening potentially contaminated seed shipments, use of alternatives to chemical fumigation, and expansion the systems approach to maintaining pest-free zones.

- Design ways to monitor the appropriateness, consistency, and environmental safety of commodity treatment protocols, including improvement of instrumentation.

- Develop means of assessing the efficacy, effectiveness, and accuracy of inspection measures to provide ongoing quality control.

- Track global occurrence and movement of pests and diseases to provide early warning, i.e., plant and animal epidemiology, and pest and disease surveys such as the Cooperative Agricultural Pest Survey and Pest Information Network.

- Develop efficient data acquisition, storage, and analysis capabilities for exotic pests to support effective decision making in the management of the AQI program.

- Maintain up to date action plans, including roles and responsibilities of institutions, for anticipated pest and disease entry.

- Expand preclearance (Anonymous 1991) capabilities and associated training to facilitate and expedite domestic inspection.

- Develop means of assessing the efficacy, effectiveness, and accuracy of inspection measures to provide ongoing quality control.

- Maintain an active liaison with the national and international plant and animal quarantine community ranging from research through operations.

- Provide benefit/cost analyses of alternative treatments and procedures.
- Provide technical consultation, training and support, i.e., certify treatment facilities and vessels, revise the PPQ treatment manual, track the status of existing program chemicals and registration of new pesticides, and help prepare technical information.

Trends in Quarantine Practices for Post-Harvest Commodities

Joe Vorgetts, Jr.

USDA, APHIS, Biologics, Biotechnology
and Environmental Protection

The first efforts in the United States to regulate agricultural commodities to prevent the introduction and spread of plant pests were made under the authority of legislation enacted by state governments. Attempts to enact similar laws at the federal level were not successful until Congress approved the Plant Quarantine Act of 1912. Since that time, federal quarantine regulatory authority has been modified by reauthorizations of the Plant Quarantine Act and expanded by the Federal Plant Pest Act of 1957 and the Federal Noxious Weed Act of 1974. These are the most significant laws that provide APHIS, PPQ the authority necessary to achieve its mission: To establish and enforce quarantine regulations for commodities moving from one state to another, and into the United States from other countries, in a manner that is least disruptive to the flow of commodities in commerce.

Quarantine regulations are codified in Title VII of the Code of Federal Regulations (CFR). Prior to being completed, proposed regulations are published in the Federal Register for review and comment. Final regulations that apply to the majority of regulated agricultural commodities are contained in two sections of the CFR. Section 7 CFR 319.56 (quarantine 56) lists post-harvest fresh fruits and vegetables by country of origin. This is a non-restrictive regulation because only listed commodities and countries are eligible for a permit. Section 7 CFR 319.37 (quarantine 37) addresses non-edible plant products. This is a restrictive regulation, i.e., listed commodities include only those that are not permitted entry into the U.S. Generally, anything that is not listed can be imported. Exceptions to quarantine 56 and 37, which relate to special quarantine requirements for specific commodities, are describe in separate sections of Part 319 of the Code.

Important trends in quarantine practices for the next decade include a shift away from reliance on commodity treatments at ports of entry (Roth 1989). Currently, these are used extensively to eliminate exotic pest infestations in imported commodities. Greater emphasis will be placed on prevention of infestation at points of origin. This will be supported by increased success in eradicating pest populations in exporting countries, introducing new pest resistant animals and plants developed by classical genetics and recombinant DNA methods, and identifying or creating pest-free pathways. For commodities that cannot be prevented from becoming infested, reliance on chemical control practices will decrease as alternative physical treatment methods are developed, i.e., temperature manipulation and ionizing radiation (Paull and Armstrong 1993). Treatment protocols involving two or more control methods are also likely to become more prevalent.

Federal Phytosanitary Program in the State of California, State and County Participation

David Lūscher
California Department of Food and Agriculture

The Federal Phytosanitary Program in California is a cooperative interagency effort that empowers state and county personnel to supplement the federal agricultural inspectors in issuing Federal Phytosanitary Certificates (FPCs) in the state. In California, the Federal Phytosanitary Certification Program is administered by USDA, APHIS in cooperation with the California Department of Food and Agriculture (CDFA) Pest Exclusion Branch and the County Agricultural Commissioners. The USDA sets the minimum requirements that state and county cooperators must meet to become authorized to issue FPCs, and provides materials and supplies to conduct the program.

The CDFA Pest Exclusion Branch works with other branches of the Department to develop specific field inspection, trapping and laboratory testing procedures that allow California commodities to be certified for entry into specific foreign countries. CDFA also oversees and manages the state and county cooperators in the daily operation of issuing FPCs. The role of the county cooperators is limited to implementation; inspecting commodities and issuing FPCs. They also observe commodity treatments to verify that they are accomplished in compliance with the requirements of foreign countries. Finally, county cooperators perform field inspections of crops grown for seed to verify that they are free of seed-borne diseases.

USDA-ARS Research in International Quarantine Programs

Robert L. Mangan, Research Leader
Crop Quality and Fruit Insect Research Unit
USDA-ARS, Weslaco, TX

The three most important factors that determine the approaches to international quarantine programs are:

1. The direction of commodity movement (import or export).
2. The sources of funding.
3. The characteristics of the countries.

When research is being carried out for commodity export from the U.S., programs are facilitated because the commodity, the pest, and the equipment are usually all local. The commodity can be procured at the proper stage of maturity, pests are usually not under quarantine, and equipment, facilities and support personnel do not have to be transported across international borders.

When USDA agencies perform research in order to import fresh commodities, research may be performed in the foreign country. In these cases equipment and supplies must be shipped to the location or constructed with local supplies and operations are usually carried out under less than favorable conditions. Local cooperators sometimes provide labor support and reduce the costs of travel for support personnel but they must be trained. Planning and scheduling are crucial to the efficiency and success of foreign research of any type. Delays in shipment of equipment due to customs permits can be significant because much of the equipment is subject to tariffs. Procuring the commodity is less of a problem but evaluations of product quality will depend on a supply of high quality commodity for testing.

When research on a foreign-produced commodity is performed in the U.S., the major problems involve access to the commodity and the pest. Both commodity and pest are likely to be subject to U.S. quarantine, so facilities for storage and rearing must be approved by APHIS-PPQ and state regulatory agencies. Shipping problems, especially delays, may cause difficulties in getting the commodity at the appropriate stage of maturity. When research is being executed with funding from foreign or private sources the type of research may be restricted. Many foreign funding sources are unwilling to support research that involves high costs without a guarantee that the treatment will succeed. Inexpensive tests to determine whether a treatment works or not may be the only testing done. Another problem with research funded from private or foreign sources is lack of understanding, especially in developing

countries, of the nature of quarantine problems. Clear communications concerning risk levels, sample sizes and quarantine status of the pest will reduce these problems. Sources supporting research need to understand that they are not simply buying a treatment.

Risk assessment for imported commodities is frequently simpler than for exports because the standards for imports are set by APHIS-PPQ and direct communication with ARS is possible. For exports, the standards may vary among countries and communication and decisions are frequently made indirectly and very slowly.

The scientific role of ARS in quarantine decisions may vary considerably. The simplest and, for most scientists, best situation is one in which ARS scientists design and execute the research, then report results for regulatory consideration and publication. Often, however, we are asked to supervise projects that are executed by foreign investigators or to review protocols and results without seeing the experiments at all, or simply review results without input in either protocols or experiments. In these cases there are problems for the ARS scientists in evaluating the adequacy of design and execution as well as determining the risk from results.

An approach that seems to minimize these problems, especially for import related research, is to develop long term cooperative relationships with foreign laboratories so that facilities, equipment, supplies and trained support personnel are available and so that projects can be designed with input from ARS scientists who can communicate with APHIS-PPQ as the research is performed.

CONCLUSION

The unusual citation of unpublished memoranda and reports in this review emphasizes the continuing importance of individual contributions, rather than institutional affiliations in the advancement of this scientific and technological field. APHIS was created by separation from ARS in 1972 and during the intervening years many individuals have transferred between the agencies. Moreover, remnants of the pre-1972 system remain relatively isolated inside both ARS and APHIS. Scientists and Practitioners in both agencies are determined to solve AQI Problems, but they come from very different professional backgrounds, have disproportionate and inadequate resources, and operate in dissimilar working environments. Consequently, much of the AQI methods development is accomplished in ARS. APHIS Methods Development has become mostly a service component of operational programs, and some of the best AQI research is accomplished in specific pest control fields. This is exemplified by research and methods development on tropical fruitflies (Faust and Coppedge 1992, Coppedge 1991, Miller et al. 1992). The way to put

"Humpty Dumpty back together again" is to establish an active, interdependent network among ARS, APHIS,other institutions and industry to unify the field of "Regulatory Pest and Disease Management."

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ARS, APHIS, AND OTHER AGENCY INTERACTIONS

PART II

SUMMARY

Moderator: Dr. Victoria Y. Yokoyama, USDA, ARS, HCRL, Fresno, CA

Dr. Kenneth Vick, USDA, ARS, NPS, Beltsville, MD
"ARS Quarantine Research Overview"

The ARS has five facilities to develop commodity treatments. The facilities are located in Miami, Florida; Weslaco, Texas; Fresno, California; Yakima, Washington; and Hilo, Hawaii. The effects of commodity treatments on the postharvest quality and condition of the product are determined in the ARS laboratory in Orlando, Florida. Exports are the number one priority. The clients of the ARS are industry and APHIS.

Dr. Victoria Y. Yokoyama, USDA, ARS, HCRL, Fresno, CA
"Exports to Pacific Rim Countries"

Quarantine treatments to control pests of regulatory concern are developed for stone fruits, hay and table grapes for export to Pacific Basin Countries including, British Columbia, Canada; Mexico; Japan; Korea; Australia; and New Zealand. The ARS interacts with Animal and Plant Health Inspection Service (APHIS), International Services; APHIS, Plant Protection and quarantine (PPQ), Export Certification Unit; APHIS, PPQ, Port Operations; APHIS, Methods and Development; California State Department of Agriculture; County Departments of Agriculture; and industry to develop the commodity treatments.

Dr. Robert L. Mangan, USDA, ARS, SARL, Weslaco, TX
"North American Free Trade Agreement"

Research concerns related to the Free Trade Agreement include safety of agricultural products, quarantine and product quality. Data for citrus production and exports from Mexico were given to illustrate the breadth and magnitude of these issues and their predicted effects on trade in fresh fruit from Mexico.

Dr. Roy E. McDonald, USDA, ARS, HRL, Orlando, FL
"Caribbean Basin Initiative"

The Caribbean Basin Economic Recovery Act or Caribbean Basin Initiative (CBI) is a program of trade, economic assistance and tax measures designed to promote economic growth in the region. ARS scientists have participated in several workshops where presentations were made on maintenance of postharvest quality of perishable horticultural commodities. Continued assistance is needed in the CBI countries.

Ms. Ellen McCloskey, USDA, OICD, FID, TIP, Washington, D.C.
"Role of OICD in Implementation of Quarantine Treatments with Other Countries"
USDA, Office of International Cooperation and Development, is a conduit for developing and middle income countries to access the expertise of the USDA including ARS, APHIS and other USDA agencies.

RESEARCH PRIORITIES

- to provide the knowledge of postharvest procedures to meet phytosanitary requirements

- to provide the knowledge of proper postharvest procedures to export quality product

- to expedite the development of quarantine treatments by improved communications with action agencies such as APHIS

North American Free Trade Agreement
Quarantine and Commodity Quality Issues

Robert L. Mangan, Research Leader
Crop Quality and Fruit Insect Research
USDA - ARS, Weslaco, TX

The North American Free Trade Agreement as proposed will reduce tariffs on many fresh commodities for import into the U.S. from Mexico. For the major commodities of quarantine interest, mostly mangoes and citrus, the current tariffs are already quite low (<5% of value) for most of the year. The major restriction to import is regulatory and the major regulatory factor is the genus *Anastrepha*. It is noteworthy that as a result of the General Agreements on Trade and Tariffs (GATT), Mexico has already opened markets to a wide variety of U.S. products including fresh and processed agricultural commodities.

As market access for fresh fruit from Mexico increases through further tariff reductions, quarantine issues will become even more important as trade barriers. We (at Weslaco) have tried to develop an information base to project what the future needs for quarantine and post-harvest quality will be with respect to changing trade situation. The tariffs are only a small part of the overall fresh fruit trade situation. In addition to quarantines, market orders, market information for both U.S. exporters and importers and competitive factors such as subsidies, loans, and tax advantages in Mexico will affect trade.

The effect of the proposed free trade agreement on research programs will not be great in comparison with other issues being discussed at this meeting. There is already a great imbalance of trade in all fresh fruit and vegetables with Mexican exports averaging 45X the imports from the U.S. In terms of total citrus production, Mexico produces about 1/3 as much tonnage of oranges, less than 1/15 the tonnage of grapefruit, and 1/2 the tonnage of tangerines as the U.S. Total exports from Mexico only average 0.3% of oranges and 2.5% of grapefruit. In addition, while Mexico has a much smaller total population of consumers than the U.S., Mexican consumption of citrus averages more than twice the kg/person as the U.S. If exports of citrus to the U.S. do increase as a result of changes brought about by NAFTA, these changes will happen gradually as the tariffs are phased out and as more acreage comes into production.

As the free trade agreement has been proposed, there are no changes in quarantine regulations or market order procedures. We interpret this to mean that the current methods for risk analysis used by APHIS-PPQ and ARS will not be changed by the agreement. The highest priority for research at Weslaco is post-harvest treatments for citrus and other fresh fruits. Resulting treatments from this research will allow shipment of fruit from areas of the U.S. such as the Rio Grande Valley of Texas and Southern California when they become periodically infested with Mexican fruit fly. Information concerning fruit tolerances to various treatments will be useful for developing treatments against other fruit flies in other areas including Mexico and other tropical American regions.

METHYL BROMIDE STATUS

SUMMARY

Moderator: P. V. Vail, USDA-ARS, Fresno, CA

This section served to bring the participants up to date on the present status of methyl bromide (MB). The issues and challenges not only have implications for quarantine, but also for soil, structural and non-agricultural treatments (timber, packing materials, etc.). Currently the issues include worker safety, environmental emissions and the potential for anthropogenic use of MB depleting the ozone layer. The latter issue is global in context. The implications for world trade are of major concern.

Only a few countries produce MB: the United States, Japan, France, Israel and possibly Russia, China and India. Production of MB from 1984-1990 increased from 45 to 62 metric tons in approximately 5.5 per year world wide. MB is one of the few substitutes that provides some of the advantages of ethylene dibromide, particularly in the areas of commodity and quarantine treatments. Over 78% of the MB used in agriculture is for pre-plant soil application. Quarantine and commodity treatment use 16% and structural application uses 3%. North America accounts for 42% of MB sold followed by Europe (28%) and Asia (22%). This combined volume accounts for 92% of world-wide usage. The remaining usage is small, but may be critical. The UNEP MB assessment panel considered alternatives to MB usage, but concluded that no single alternative exists for current uses. There are few alternatives that are proven commercially as related to the issues of postharvest/quarantine insect control. If MB is listed as an ozone depleting substance (Class I) by the Montreal Protocol, it automatically is listed under the U.S. Clean Air Act. It is estimated that 70% of MB is produced by the oceans.

The dependency upon this chemical by many countries is obvious and the U.S. Animal and Plant Health Inspection Service (APHIS) is almost completely dependent upon MB availability for quarantine use. Consumption is about equal between food and non-food uses. In 1991, there were 5,429 quarantine treatments applied nation wide, usually in major ports, consuming a total of 385,000 pounds of MB. The diversity of MB uses makes developing alternatives to cover all uses very difficult. Physical treatments such as high and low temperatures, controlled atmospheres and other alternatives may be more commodity or cultivar specific than MB and the phytotoxicity thresholds as related to quarantine security must be firmly established.

There is an urgent need to inventory the fate of MB during and after fumigation for all issues pertaining to MB, i.e., ozone depletion, worker safety,

environmental emissions, etc. Without this information, it will be very difficult to access technologies that could be used to relieve environmental emissions. If this information is available, scrubbing or recycling of MB can be pursued logically.

There was general agreement it would be prudent to reduce emissions in order to demonstrate concern about compliance. The paucity of data in regards to the cause and effect relationship of MB emissions to ozone depletion was questioned by a number of participants. Although chemical alternatives to MB were discussed, there was general consensus that none are available that would not pose potential problems from a registration, efficacy and phytotoxicity standpoint.

Recently, methyl bromide has been implicated as an ozone depleting substance by the Parties to the Montreal Protocol causing great concern in the agricultural community as it is commonly used for soil, commodity, and structural fumigation. It is particularly important for use in quarantine treatments to prevent the introduction of arthropod pests into new locations. Because of the potential impact of methyl bromide loss, a number of meetings has been held by the United Nations Environment Programme (UNEP) on behalf of the Parties to the Montreal Protocol and other groups. An "International Conference on Controlled Atmospheric Storage and Fumigation for Insect Control - Current Research from Several Countries" was held in Winnipeg, Canada, June 11-13, 1992. Two meetings organized by UNEP and several United States agencies during 1992 were held in Washington, D.C.: International Methyl Bromide Science Workshop, June 2 and 3, and the International Workshop on Alternative and Substitutes to Methyl Bromide, June 16-18. Two more meetings of the Technical Options Committee were held in 1993 at the Hague, Netherlands, and in East Africa. In the fall of 1992, USDA-ARS, USDA-APHIS, and university scientists also met in Washington, D.C. to identify and describe the potential and practicality of possible alternatives. In June of 1993, a USDA sponsored meeting priortized the potential alternatives and set research goals in cooperation with federal, university, state and private institutions.

RECOMMENDATIONS

- Methods for controlling emissions must be developed.
- Alternative treatments such as heat, cold, controlled atmospheres and radiation need to be developed.
- Systems approaches need to be developed that provide adequate security. More than one "treatment" may be required.

- We need to know more about the postharvest biology of quarantined organisms.

- Pest-host relationships need to be further quantified in order to extend the concept of non-host status or pest free zones.

- New and innovative methods of insect control must be developed that will alleviate regulatory and environmental concerns.

- We need to know more about the predisposing causes of phytotoxicity in order to alleviate such concerns.

- Efficient methods of monitoring effectiveness of single, combination or systems quarantine treatments must be developed.

Methyl Bromide Production and Uses

Dr. R. Franklin Handy
Research Associate, Great Lakes Chemical Corporation, West Lafayette, IN

Methyl Bromide is a fumigant widely used in production agriculture. It is used in pre-plant soil applications, in quarantine and non-quarantine commodity protection, and in structural applications. The June 1992 Methyl Bromide Interim Technology and Economic Assessment sponsored by the United Nations Environment Programme (UNEP) concluded that "For the broad spectrum of applications in which it is currently used, there is no single alternative or substitute for methyl bromide." The advantages and disadvantages of the substitute chemicals and alternative procedures were reviewed. While the replacement of a portion of the methyl bromide currently used was viewed as possible, the range or the estimates of applications fraction that could be replaced was wide, 30 to 90 %, suggesting substantial uncertainty.

PRODUCTION

Methyl bromide is generally produced by the reaction of hydrobromic acid (HBr) and methanol (CH3OH). It can also be produced from elemental bromine, using sulfur to convert the elemental bromine to hydrobromic acid. The overall reaction is

$$6CH_3OH + 3Br_2 + S \rightarrow 6CH_3Br + H_2SO_4 + 2H_2O$$

but can be broken down into a two step reaction

$$3Br_2 + S + 4H_2O \rightarrow 6HBr + H_2SO_4$$

$$6HBr + 6CH_3OH \rightarrow 6CH_3Br + 6H_2O$$

illustrating that the methyl bromide formation reaction involves hydrogen bromide and methanol. More than 75% of the total methyl bromide production is believed to be manufactured by the methanol/HBr route.

The total world production is listed in TABLE I for the years 1984 to 1990. During that time period, production increased at a rate of about 5.6% per year. Methyl bromide is produced in the United States, Israel, Japan and France. The methyl bromide industry believes that some methyl bromide is produced in the

former Soviet Union, in China, and in India. However, the presumed small volume involved is not known.

The man-made production of methyl bromide represents from 15 to 35 % of the total amount of methyl bromide emitted to the atmosphere. The wide range indicates the uncertainty in many of the factors that must be known in order to accurately determine this value.

USES

A tabulation of the sales of methyl bromide by use category is shown in TABLE II. The major use category is pre-plant soil fumigation, accounting for about 78% of the non-industrial use of methyl bromide. Quarantine and non-quarantine post-harvest uses account for about 16% of the non-industrial use of methyl bromide. Use as a structural (e.g., flour mills, etc.) fumigant accounts for 3% of the non-industrial methyl bromide used. Use as a residential/commercial fumigant accounts for 2.4% of the use of methyl bromide in non-industrial applications.

A tabulation of the sales of methyl bromide by region is shown in TABLE III. The greatest use is by North America, accounting for about 42% of sales. The second and third largest regions for sales are Europe (about 28%) and Asia (about 22% of sales).

As a soil fumigant, methyl bromide is a broad spectrum biocide injected into soil prior to planting crops to control plant parasitic nematodes, soil-borne disease organisms, weeds and insects. Crops protected are asparagus, broccoli, cauliflower, eggplant, lettuce, muskmelon, onions (dry bulb), peppers, pineapples, strawberries, tomatoes, citrus, vineyards, and deciduous fruits and nuts (TABLE IV).

As a quarantine/non-quarantine (commodity) fumigant, methyl bromide is a broad spectrum fumigant used at ports-of-entry to protect against the introduction of exotic pests into new territories, in food producing establishments to prevent the introduction of filth into consumer food, and in food storage areas to prevent the loss of edible commodities through the contamination or consumption by pests. A large number of raw and processed foods are protected by methyl bromide (TABLE V).

ALTERNATIVES

Quarantine and non-quarantine commodity treatments require 100%

effectiveness, and there are currently no foreseeable alternatives according to the UNEP Report of June 1992. For durable and non-food commodities potential alternatives to methyl bromide (TABLE VI) include phosphine fumigation, residual chemical treatment, irradiation, biological control, atmospheric modification, and thermal procedures. The advantages and disadvantages of methyl bromide replacements for insect disinfestation of durable and perishable foodstuffs are shown in TABLE VII.

The savings or additional costs of using alternatives to methyl bromide are unknown to a large extent. Savings are related to differences in treatment costs due to the lower cost of chemicals, or the absence of chemicals. Additional costs are related to the cost of changes in growing practices, the purchase of new or the modification of old equipment, greater manpower requirements, greater use of substitutes, incremental use of co-applied chemicals, and added treatment time.

RECOMMENDATIONS

To reduce the uncertainties about the role of methyl bromide in ozone depletion, the UNEP Assessment recommended research during the next two years to (1) determine the global abundance of methyl bromide in the troposphere and the stratosphere; (2) define the magnitude of the man-made sources of methyl bromide; (3) identify and quantify the natural sources and natural removal processes for methyl bromide; and (4) understand the role of bromine in the ozone depletion processes in the stratosphere.

In addition, research is needed to identify the efficacy of alternate treatments and the capital and operating costs of switching from methyl bromide to alternatives in order to define the economic impact of using the alternatives. Advanced practices and equipment as well as new application technologies are needed to minimize methyl bromide emissions.

TABLE I
A Tabulation of the Total Production of Methyl Bromide on an Annual Basis for the Period 1984 through 1990 from Reporting Companies

(Metric Tons)

Year	Production
1984	44,856
1985	48,013
1986	48,754
1987	56,224
1988	61,546
1989	64,628
1990	61,724
Total	385,745

TABLE II

A Tabulation of Methyl Bromide Sales by Use Category
For Years 1984 through 1990 from Reporting Companies

(Metric Tons)

Year	Pre-Plant	Post Harvest	Structural	Residential/ Commercial	Chemical Intermediates	Total Sales
1984	30,408	9,001	1,285	881	3,997	45,572
1985	33,976	7,533	1,274	983	4,507	48,273
1986	36,090	8,332	1,030	999	4,004	50,455
1987	41,349	8,708	1,763	1,160	2,710	55,690
1988	45,131	8,028	1,910	1,737	3,804	60,610
1989	47,542	8,919	2,083	1,530	2,496	62,570
1990	51,306	8,411	1,740	1,494	3,693	66,644
Total	285,802	58,932	11,085	8,784	25,211	389,814

TABLE III
A Tabulation of Methyl Bromide Sales by Region
For Years 1984 through 1990 from Reporting Companies

(Metric Tons)

Year	North America	South America	Europe	North Africa	Africa	Asia	Australia	Total Sales
1984	19,659	1,389	11,364	183	1,595	10,678	704	45,572
1985	20,062	1,503	14,414	45	1,975	9,743	531	48,273
1986	20,410	1,774	13,870	380	2,205	11,278	538	50,455
1987	23,004	1,820	15,359	385	1,751	12,816	555	55,690
1988	24,848	2,058	17,478	277	1,582	13,555	812	60,610
1989	26,083	1,701	16,952	618	2,075	14,386	755	62,570
1990	28,101	1,621	19,119	432	1,838	14,605	928	66,644
Total	162,167	11,866	108,556	2,320	13,021	87,061	4,823	389,814

Table IV

CROPS PROTECTED BY METHYL BROMIDE
SOIL FUMIGATION

ASPARAGUS

BROCCOLI

CAULIFLOWER

EGGPLANT

LETTUCE

MUSKMELON

ONIONS (DRY BULB)

PEPPERS

PINEAPPLES

STRAWBERRIES

TOMATOES

CITRUS

VINEYARDS

DECIDUOUS FRUITS AND NUTS

TABLE V

COMMODITIES PROTECTED BY METHYL BROMIDE QUARANTINE AND NON-QUARANTINE USE

STORED PRODUCTS

Almonds
Brazil Nuts
Bushnuts
Butternuts
Cashews
Chestnuts
Filberts
Hickory Nuts
Peanuts
Pecans
Pistachios
Walnuts
Apples
Apricots
Blueberries
Cherries
Nectarines
Peaches
Pears
Plums
Quinces
Strawberries
Prunes
Barley
Corn
Oats
Popcorn
Rice
Rye
Sorghum (grain)
Dried Peas
Wheat
Copra
Beans (all)
Beets (roots)
Cabbage
Cantaloupe
Carrots
Citron
Cucumbers
EggPlant
Honeydew Melons
Jerusalem Artichokes
Muskmelons
Okra
Onions
Parsnips (roots)
Peas (with pods)
Sweet Corn
Peppers
Pimentos
Pineapple
Potatoes
Pumpkins
Radishes
Squash (summer)
Squash (winter)
Squash (zucchini)
Sugar Beets (roots)
Sweet Potatoes
Tomatoes
Turnips (roots)
Watermelons
Yams
Cipolini Bulbs
Cocoa Beans
Cotton Seed
Garlic
Horseradish (roots)
Salsify Roots
Hay (alfalfa)
Grapefruit
Grapes
Kumquat
Lemons
Lime
Oranges
Tangelos
Tangerines
Baled Tobacco
Processed Tobacco
Baled Cotton

PROCESSED FOOD

Apples (dried)
Apricots (dried)
Cherries (dried)
Dates
Figs (dried)
Peaches (dried)
Prunes (dried)
Raisins (dried)
Cheese (parmesan and roquefort)
Eggs (dried)
Ham Houses
Processed Foods
Processed Grains
Herbs and Spices (dried)
Animal Feed

STRUCTURES CONTAINING RAW OR PROCESSED COMMODITIES

Warehouse
Grain Elevator
Food Processing Plant
Restaurant
Feed Room
Grain Bin

TABLE VI

METHYL BROMIDE ALTERNATIVES
DURABLE AND NON-FOOD COMMODITIES

PHOSPHINE FUMIGATION

RESIDUAL CHEMICAL TREATMENT

IRRADIATION

BIOLOGICAL CONTROL

ATMOSPHERIC MODIFICATION

THERMAL PROCEDURES

Table VII

Options and Alternatives for Insect Disinfestation of Durable and Perishable Foodstuffs

	Methyl Bromide	Phosphine	Controlled Atmospheres	Irradiation
Treatment duration	· up to 24 hrs + purging aeration	· 3-15 days + purging/aeration	· 3-40 days	· few minutes exposure in flow systems
Minimum temperature needed	4°C	15°C	15°C	n.a.
Quality of product	· good · some perishable foods sensitive to methyl bromide	· good	· good	· good · unsuitable for seed for malting and germination · may extend shelf life of certain perishables
Health effects: Workers	· acutely toxic if directly exposed · TLV = 5 ppm[1] · HBROEL = 0.3[2] (Netherlands)	· acutely toxic if directly exposed · TLV = 0.3 ppm[1]	· presumed safer than chemical fumigation · TLV = 5000 ppm[1] (CO_2) · suffocation in high concentrations	· safe for workers if facility properly shielded and operated
Environmental effect	· deplete the ozone layer · release of toxic chemicals in to environment	· release of toxic chemicals into environment	· does not pollute environment · may be energy intensive	· some versions involve use, transportation and disposal of radioactive materials
Use (durable and/or perishable commodities)	· widely used and cost effective	· requires assessment on a product by product basis · generally suitable for durables	· requires assessment on a product by product basis · generally suitable for durables	· requires assessment on a product by product basis · generally suitable for durables
Other considerations	· requires little capital investment · requires gas-tight construction	· insect resistance problems · requires gas-tight construction	· longer kill times could require construction of additional treatment chambers · alteration of existing storage facilities to make them gas-tight · initially high capital investment	· requires large capital investment · may require labelling of treated product · potential for consumer resistance (radiation concern) · siting permits may be required

n.a. = not applicable

1 TLV = Threshold Limit Value
2 HBROEL = Health-Based Recommended Occupational Exposure Limit

Table VII (cont'd)

Options and Alternatives for Insect Disinfestation of Durable and Perishable Foodstuffs

	Heat	Cold	Chemical Protectants	Biological Control	Multiple Decrement[1]
Treatment duration	· few minutes in flow system · 1-36 hours in a batch system	· days to months based on temperature and commodity	· few days to control mobile pests	· may be less than 24 hours.	· variable
Minimum temperature needed	> 38°	n.a.	10°C	agent specific	variable
Quality of product	· good · needs careful control · there may be heat damage in some products	· very good · some products may suffer cold damage	· good	· good · dose dependent · may require product cleaning	· good
Health effects: Workers	· none	· none	· requires safety precautions during applications and handling	· none identified	· none if safety requirements met
Environmental effect	· may be energy intensive	· may be energy intensive	· disposal of excess may be a problem	· none	· commodity specific
Use (durable and/or perishable commodities)	· in use and under research for perishables · generally suitable for durables	· in use and under research for some pest on certain perishables · generally suitable for durables	· in use for durables and perishables	· potential for use in both durables and perishables	· limited current use · large research base for quarantine treatment
Other considerations	· may require large capital investment · longer treatment = higher operating costs	· may require large capital investment · slow action restricts use · longer treatment = higher operating costs	· potential for consumer resistance (chemical residue concern) · potential for insect resistance	· may be used as long term protectants · most are very specific for quarantine treatments	· not generally accepted by regulators · time consuming to validate and monitor for quarantine treatments

[1] Multiple decrement = reduction in pest populations at each stage of the "field-to-packed carton" chain.

n.a. = not applicable

Anthropogenic Methyl Bromide as an Ozone Depletor

Tom Duafala. Ph.D., TRICAL, Hollister, CA

In 1991 at the request of the United Nations Environmental Program, the World Meteorological Organization issued a report, "Scientific Assessment of Ozone Depletion: 1991". This report reviewed the current state of knowledge on the relationship between anthropogenic release of chemicals, such as halons and CFCs, and their role in ozone depletion. In this report, reference was made to the possible link between man-made methyl bromide and ozone depletion. As a result, in December of 1991, the NRDC and Friends of the Earth filed a petition with the Environmental Protection Agency under the Clean Air Act to list methyl bromide as a regulated ozone depletion chemical. In the summer of 1991, the agency responded to the NRDC petition. This response went through considerable government review and in January, 1993, was submitted for publication in the Federal Register.

Independent of the U.S. government action under the Clean Air Act, the international community under the Montreal Protocol also reviewed man-made methyl bromide's role in ozone depletion. At the November, 1992, Montreal Protocol meeting, the delegates voted to list methyl bromide as a regulated chemical, but agreed that the scientific and technical data base was much too limited to make final decisions on a phase out. This issue will be reviewed by the Montreal Protocol Parties at their 1994 meeting.

Section I: Impact of Bromine On the Ozone Layer

Bromine containing compounds, such as halons and methyl bromide, enter the lower stratosphere in the tropics where they photo-decompose to release bromine atoms. These bromine atoms are then free to participate in a series of chemical reactions, such as those shown in Figure 1. These bromine catalyzed ozone reactions occur at about the 25 kilometer altitude. As seen In Figure 2, bromine reacts with ozone to produce BrO. This BrO then reacts with ClO to remove additional ozone molecules. This increases the efficiency of bromine as an ozone depletor. It is thought that most of the bromine catalyzed ozone removal in the lower stratosphere occurs primarily by the reaction between BrO and ClO (WMO, 1992). Bromine is thought to be forty times more efficient at removing ozone than chlorine on a per molecule basis. BrO has been measured in the lower stratosphere at concentrations from 0 to approximately 10 parts per trillion.

Section II: Abundance of Methyl Bromide in the Troposphere

Numerous measurements have been taken in the troposphere (the area between the surface of the earth and approximately 10 kilometers). These measurements indicate that the concentration of methyl bromide varies between 8 and 26 parts per trillion (See Table 1). Measurements were taken in both the northern and southern hemisphere. The variation in measurement values is most probably due to the lack of good calibration standards for methyl bromide. When comparing measurement data from within the same data set, for the northern hemisphere to the southern hemisphere, an inter-hemispheric gradient of 1.3 is observed. The highest concentrations of methyl bromide are measured in the northern hemisphere.

Section III: Anthropogenic Methyl Bromide

Methyl bromide has many uses in both agriculture and as a chemical intermediate. Agricultural uses include pre-plant soil fumigation: post-harvest commodity fumigation; quarantine treatments; and structural or space fumigation. In 1990, total world sales were estimated to be 66.6 metric tons with approximately 51.3 metric tons being used for pre-plant soil use (See Table 2). It has been estimated that of all the methyl bromide used as an agricultural fumigant, approximately 50% could be emitted to the atmosphere, or approximately 30 metric tons in 1990. In order to estimate emission from agricultural use, the Methyl Bromide Industry Panel, under the CMA, funded a modeling study by D. Reible of Louisiana State University. In this study, it was shown that emissions could vary from 28% to 53%. depending upon the method of application and the condition of the soil (See Table 3). When methods of application were compared to acres treated with typical soil types, it was estimated that approximately 47% of pre-plant methyl bromide could be emitted, with potentially up to 80% of post-harvest applications emitted to the atmosphere. It if is assumed that man-made methyl bromide is responsible for the inter-hemispheric gradient, then through the use of models one can estimate that man-made methyl bromide is contributing approximately 25 (plus or minus 10%) of all methyl bromide emitted to the atmosphere. The remainder comes from natural sources; most likely, the ocean.

Section IV: Assessment of Anthropogenic Methyl Bromide As An Ozone Depletor

As an aid to policy makers, atmospheric scientists developed the concept of an ozone depletion potential (ODP) as a way of assessing a chemical's ability to deplete ozone. An ozone depletion potential is defined as the amount of zone destroyed by 1 kilogram of a compound, compared to the amount of ozone destroyed by the 1 kilogram of CFC-II (CFC-II has an ozone depletion potential

of 1). Methyl bromide's ODP has been calculated to be 0.7. The ozone depletion potential is based upon several factors such as the atmospheric lifetime of the compound in question, the release rate of bromine or chlorine from the compound in the stratosphere, and the efficiency of bromine to chlorine in the stratosphere. The lifetime of methyl bromide has been estimated to be 1.6 - 2.1 years. This is based on the reaction of methyl bromide with the hydroxyl radical in the troposphere. If other removal processes are significant: such as reaction of methyl bromide molecules with the surfaces of vegetation, soil. and surface water, then the tropospheric lifetime of methyl bromide would be shortened considerably. The impact on this would be a reduction in the calculated ODP.

Section V: Uncertainties Association With Methyl Bromide's Role in Ozone Depletion.

Before we can develop a clear understanding of man-made methyl bromide's role in ozone depletion, several uncertainties need to be addressed: such as, tropospheric removal processes, bromine chemistry, and better atmospheric measurement data. Based on limited data and modeling, man-made methyl bromide could have accounted for about 1/20 to 1/10 of the current observed global ozone loss of 4 - 6 %. The following outline details research needs:

RESEARCH NEEDS: METHYL BROMIDE

Research related to the role of anthropogenic methyl bromide to ozone depletion:

1. Absolute calibration for CH_3Br and better guantitation of CH_3Br measurements.

2. Determination of tropospheric removal processes (sinks) for methyl bromide such as soil, vegetation, and surface waters.

3. Elucidation of stratospheric bromine chemistry.

4. Elucidation of anthropogenic and natural sources for methyl bromide.

5. Quantitate emissions from agricultural use.

6. Develop emission reduction strategies for pre-plant soil use of methyl bromide such as:
    a. Study different delivery systems such as the noble plow

b. Study different fumigation film types
c. Study depth of injection
d. Combinations of better delivery system, optimum injection depth, better barrier film, and dosage reductions
e. Effect of soil moisture on emissions
f. Effect of soil organic matter on emissions

RESEARCH NEEDS: CHEMICAL ALTERNATIVES

1. Chemicals to be tested:
   a. Methyl bromide chloropicrin mixtures (67/33) as a reference material
   b. 100% chloropicrin
   c. Chloropicrin telone mixtures
   d. Telone II
   e. Basamid
   f. Metham sodium
   g. Metham sodium + chloropicrin
   h. Enzone (Unical product that produces carbon disulfide)
   i. Other ?

2. Variables to be considered for above alternatives:
   a. Dosage
   b. Delivery system e.g. drip, injection, etc.
   c. Soil moisture
   d. Soil type
   e. Pest to be controlled
   f. Crop system. e.g. strawberries, peppers. etc.
   g. Tarp vs. No tarp
   h. Depth of application
   i. In combination with some sort of pre-conditioning, such as solarization

3. Data to be generated for all chemical alternatives:
   a. Effect of different rates on efficacy of the product
   b. Comparison of different delivery systems vs. efficacy
   c. Efficacy studies by assaying soil before and after treatment, or burying inoculum such as weed seeds, nematodes, fungi
   d. Residue studies
   e. Lab toxicity studies on different target pests
   f. Growth response of crop
   g. Measurement of chemical movement in soil e.g. lateral and downwind movement
   h. Flux studies and off-site movement of chemical
   i. Movement in soil/water

j. Soil data for each trial
   (1) ph
   (2) organic matter
   (3) bulk density
   (4) characterization
   (5) moisture
k. Factors affecting phytotoxicity to the crop
l. Weather data
   (1) Wind
   (2) Temperature
   (3) rain fall

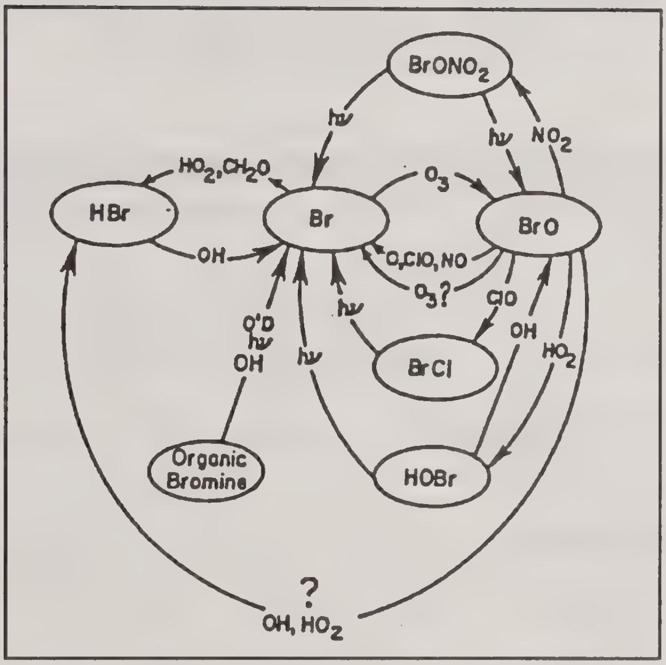
RESEARCH NEEDS: NON-CHEMICAL ALTERNATIVES

1. Solarization
2. Soil amendments
3. Heat/steam
4. Bio-control
5. Combination of chemical and non-chemical alternatives

RESEARCH NEEDS: EMISSION REDUCTION FOR USE OF METHYL BROMIDE

1. Study different delivery systems, such as the noble plow
2. Study different fumigation film types
3. Study depth of injection
4. Combinations of better delivery system, optimum injection depth, higher barrier film, and dosage reductions.
5. Effect of soil moisture on emissions
6. Effect of soil organic matter on emission

FIGURE 1



Gas Phase Bromine Cycle

Montreal Protocol Assessment Supplement
Methyl Bromide: Its Atmospheric Science
Technology, and Economics
1992, United Nations Environment Program

Figure 2

BROMINE INDUCED OZONE DESTRUCTION

$$Br + O_3 \rightarrow BrO + O_2$$

$$Cl + O_3 \rightarrow ClO + O_2$$

$$ClO + BrO + (hy) \rightarrow Cl + Br + O_2$$

$$\text{Net} \quad 2O_3 \rightarrow 3O_2$$

Montreal Protocol Assessment Supplement
Methyl Bromide: Its Atmospheric Science
Technology, and Economics
1992, United Nations Environment Program

Table 1

Atmospheric Abundances of Methyl Bromide (ppt)*

Time Period	Northern Hemisphere	Southern Hemisphere	References
1981	26	20	Singh et al., 1983
1982-83	15	11	Penkett et al., 1985
1983-92	11	8	MBSW, 1992
1985-87	12	10	Cicerone et. al, 1988
1991	10	8	MBSW
1991	14	-	MBSW

*Measurements taken at or near ground level, "less than 1 Km".

Table 2

Methyl bromide sales, in thousands of tons*

Year	Pre-Planting	Post-Harvesting	Structural	Chemical Intermediates**	Total	Available for Release to Atmosphere
1984	30.4	9.0	2.2	4.0	45.6	41.6
1985	34.0	7.5	2.3	4.5	48.3	43.8
1986	36.1	8.3	2.0	4.0	50.4	46.4
1987	41.3	8.7	2.9	2.7	55.6	52.9
1988	45.1	8.0	3.6	3.8	60.5	56.7
1989	47.5	8.9	3.6	2.5	62.5	60.0
1990	51.3	8.4	3.2	3.7	66.6	62.9

*Production by companies based in Japan, Western Europe, and the USA.
** Not released into the atmosphere.

Table 3

Cumulative Methyl Bromide Losses to the Atmosphere Effect of Varying Application Parameters	
Case 2% organic carbon soil excepted as noted	Methyl Bromide Lost - 14 Days
Base 10" injection, 2 day cover	45%
6" injection, 2 day cover	53%
18" injection, 2 day cover	28%
18" injection, no cover	29%
10" injection, 7 day cover	33%
10" injection, 2 day cover 4% organic carbon	37%

D. Reible, June 4, 1992
MBSW, Washington D.C.

Quarantine Issues of Methyl Bromide, Present and Future

Robert W. Berninger, Center Director USDA, APHIS, PPQ,
Hoboken Methods Development Center, Hoboken, NJ

If we lost Methyl Bromide today millions of dollars of commodities would be unable to move from any seaport or international airport in the United States. Export commodities like tobacco to most of the world, cherries to Japan, peaches and nectarines to Mexico and oak logs to the European community could not be marketed. Import commodities, such as fruit from all over the world, brassware from Bombay, skins from Sudan and Pakistan, used truck tires from Asia, and cut flowers from Asia, Europe, and South America could not be marketed.

APHIS depends on methyl bromide (MB) as the fumigant for quarantine treatments. The loss of cyanide and ethylene dibromide was insignificant compared to a loss of MB Quarantine treatments are conducted under temporary enclosures and in chambers, with the majority being under temporary enclosures. All the fumigation reports from PPQ, except from inspection stations are sent to the Hoboken Methods Development Center. These reports are analyzed for the correct treatment and applicability in regards to the Treatment Manual, the label, Section 18 exemption, and crisis exemption. These reports are then tallied by port, commodity, food or non-food, label and section 18 treatment. This information is then transmitted to the Technical Support Staff, in Hyattsville, on a monthly basis and in turn to the EPA.

In fiscal 1991, there were 5,429 quarantine treatments nationwide using 385,525 pounds of MB Figure 1 shows the breakdown of treatments for fiscal 1991 for food and non-food commodities. The treatments for plant pests are broken down in Table 1 for perishable commodities that have mandatory treatments. Non-food, mandatory treatments are shown in Table 2. Table 3 shows the four most common commodities fumigated for intercepted pests. The relative amounts of methyl bromide used are ranked in Table 4. Four groups of mandatory treatments make up 81% of commodity fumigation usage. The four most important treatment groups for intercepted insects use a much smaller percentage of MB used for commodity fumigation.

We have discussed MB in the present, but what about the future? As long as we have MB we must perform treatments in the safest and least detrimental manner to the environment as possible. However, we should not be caught short as we were with ethylene dibromide. We must forge ahead with alternate treatments. We recommend that highest priority be given to commodities in Table 4.

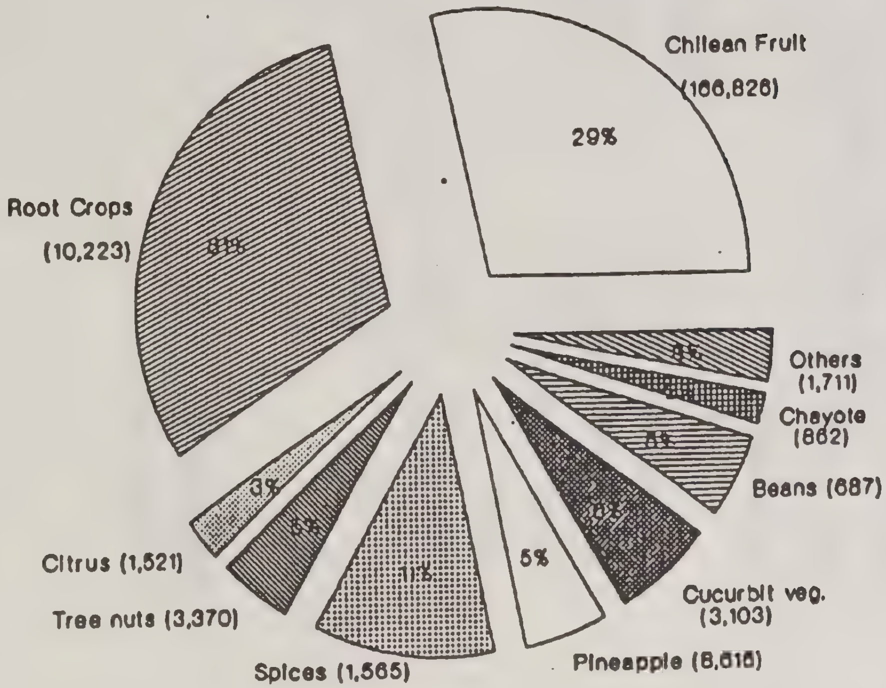
Figure 1.

Methyl Bromide Fumigations

APHIS Port Operations (10-01-90 to 09-31-90)

Food

Methyl Bromide (lbs.): 198,484
Total Treatments: 2,649



Non-Food

Methyl Bromide (lbs.): 187,041
Total Treatments: 2,780

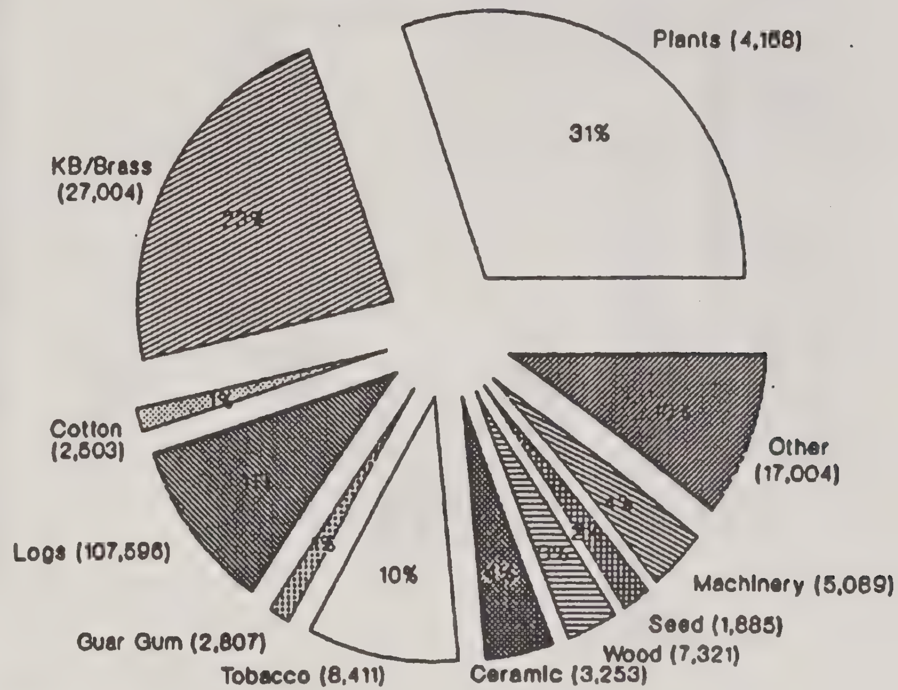


Table 1.

PERISHABLE COMMODITIES
MANDATORY MB TREATMENT

COMMODITY	(#) TREATMENTS	(%) TOTAL
CHILEAN FRUIT	752	13.85
YAMS	746	13.74
THYME	175	3.22
CHESTNUTS	120	2.21
STRING BEANS	60	1.10
CITRUS	54	0.99
PEAS	43	0.79
OKRA	16	0.29
FABA BEANS	6	0.11
GARLIC	3	0.055
PRICKLY PEAR	2	0.03
	----	----
	1977	36.42

Table 2.

MANDATORY TREATMENTS WITH MB FOR KAPRA BEETLE

COMMODITY	(#)TREATMENTS	(%)TOTAL
	IMPORT	
BRASSWARE	638	11.75
CUCURBITAE SEED	44	0.81
PLANT GUMS	42	0.77
SKINS	16	0.29
USED JUTE	4	0.07
OTHER	15	0.27
	759	13.98
	EXPORT	
OAK LOGS	289	5.32
TOTAL TREATED	3,025	55.72

Table 3.

Commodities Treated for
Intercepted Insects

COMMODITY	(#)TREATMENTS	(%)TOTAL
CUT FLOWERS	762	14.0
PINEAPPLES	137	2.5
PLANTS	63	1.2
MELONS	56	1.0
	----	----
total	1018	18.7%

Table 4.

METHYL BROMIDE USAGE

COMMODITY	POUNDS	
CHILEAN FRUIT	166,826	
OAK LOGS	107,596	
K.B.BRASSWARE	27,004	
YAMS	9,072	
	--------	
total	310,488	81% total usage:
INTERCEPTED INSECTS	19% total treatments	
pineapples	8,616	
cut flowers	3,025	
plants	1,143	
melons	1,016	

	13,800	3.6% total usage

ALTERNATIVE TREATMENTS

SUMMARY

Moderator: Dr. Harvey Chan, Research Leader, USDA, ARS, Hilo, HI

Due to Hurricane Andrew there were several program changes in this particular session. Dr. Guy Hallman, Research Entomologist, Miami, Florida who was assigned as moderator of this session and who also was presenting a talk on "Ornamentals" was unable to attend the workshop. Substituting for Dr.Hallman was Harvey Chan as the moderator and Dr. Vicki Yokoyama as speaker on "Ornamentals". The program was further modified by the addition of an additional speaker, Dr. Eric Jang, who spoke on "Systems Approaches" as an alternative treatment.

A review of each of the speakers summaries will show that the alternative treatments currently being researched are as follows:

1. Temperature Control
   a. High temp.- water bath, vapor heat, dry heat, dielectric,

   b. Low temp. - refrigeration at 0 - 5°C

2. Controlled atmospheres - low oxygen

3. Irradiation

4. Film packaging/coatings

5. Host status

6. Systems approach - also includes, handling practices, field sanitation, visual inspection, transportation, storage.

7. Combination treatments of the above listed treatments.

As pointed out during the ensuing discussion that although there appears to be a number of potential alternatives to methyl bromide fumigation as a quarantine treatment none of the potential alternatives will find such a universal application as a generic treatment. Each proposed potential alternative treatment will need to be researched on a case by case basis which is time consuming and costly. A generic approach to heat and cold treatments might help speed the development of treatments. The discussion then shifted to the appropriateness of the "Probit 9" philosophy in view of the emerging systems approach to

quarantine treatments. Many scientists felt that "Probit 9" although a useful tool of the past which was appropriate for quietus treatments such as fumigation of ship holds has become a paradigm and a hinderance to innovative approaches to development of quarantine treatments.

Tropicals, Subtropicals, Ornamentals

Dr. Victoria Y. Yokoyama, USDA, ARS, HCRL, Fresno, CA

Alternative treatments to chemical fumigants that have been developed to control pests of regulatory concern on tropical and subtropical commodities and ornamental plants are listed for each ARS quarantine research laboratory as follows:

USDA, ARS, Miami, FL

Pests: Caribbean fruit fly, sweet potato weevil, banana moth, papaya fruit fly

Commodities: grapefruit, lime and other citrus, sweet potato, Dracena canes, mango, carambola, guava, papaya, avocado, sapote

Alternative Treatments: hot air, vapor heat, irradiation, hot water dips, coatings, non-host status

USDA, ARS, Hilo, HI

Pests: Oriental fruit fly, melon fruit fly, Mediterranean fruit fly, Malaysian fruit fly

Commodities: papaya, avocado, carambola, litchi, mango

Alternative Treatments: cold, vapor heat, hot water immersion, high temperature forced air, film packaging, combination treatments

USDA, ARS, Weslaco, TX

Pests: Mexican fruit fly, West Indian fruit fly, guava fruit fly, *Anastrepha serpentina*

Commodities: citrus, mango, guava, minor New World tropical fruit
Alternative Treatments: hot forced air, vapor heat, hot water, modified atmospheres, host status, fly free zones

USDA, ARS, Miami, Fl. and Hilo. HI

Pests: Ants, banana moth, heteropterans, miscellanous insects and mites

Ornamentals: Cut flowers such as anthuriums, orchids, heliconias, ginger, foliage such as Dracena canes, other floral material and horticultural products

Alternative Treatments: Field sanitation and insecticide application, visual inspection, insecticicidal dips, vapor heat. hot water dips

Stone fruits/Tree Nuts/Grapes

Dr. Victoria Y. Yokoyama, USDA, ARS, HCRL, Fresno, CA

Compression is under development as an alternative to hydrogen phosphide fumigation for control of Hessian fly, *Mayetiola destructor* (Say), in six species of hay for export to Japan where the pest is not found. Compression is compatible with contemporary handling procedures used for exported hays.

Alternative control tactics to methyl bromide fumigation under development to control codling moth *Cydia pomonella* (L.) in nectarines for export to Japan include, high and low temperatures, insect growth regulators, host acceptability and behavioral chemicals. High temperature is not practical for use on stone fruit but may control the codling moth in walnuts with minimum damage to the commodity. Low temperature to control codling moth is compatible with stone fruit handling procedures and may be efficacious if combined with other control tactics. Insecticides are not good alternatives to fumigants for postharvest pest control because they may present human health risks and environmental problems similar to chemical fumigants. Knowledge of insect-plant interactions and behavioral chemicals can be used in stone fruit production practices to lower field infestations.

A high temperature treatment has been developed to control oriental fruit moth, *Grapholita molesta* (Busck), in stone fruits for export to British Columbia. Low temperature storage and insect growth regulators have also been studied as potential alternatives to methyl bromide. Alternatives to chemical fumigants are not as efficacious and require longer periods to develop as quarantine treatments than methyl bromide. The oriental fruit moth has recently presented a quarantine problem for stone fruits exported to Mexico. Our research on the use of methyl bromide and alternative treatments to control the pest in stone fruit to British Columbia was used by regulatory agencies to develop a quarantine treatment for stone fruit exported to Mexico.

Low temperature storage is under development as a quarantine treatment to control omnivorous leafroller, *Platynota stultana* (Walsingham), and thrips in table grapes for export to Australia.

Systems Approaches

Dr. Eric Jang, USDA, ARS, TFVRL, Hilo, HI

A systems approach to the development of postharvest quarantine security against insects was discussed and compared with other disinfestation procedures. The systems approach is a concept which has evolved in response to the need to consider the various pre and postharvest biological factors which can influence the level of infestation leading up to and including the sorting, packing, shipping and marketing of commodities. The systems approach can be defined as the integration of those pre and postharvest practices used in the production, harvest, packing and distribution of a commodity which cumulatively meet the requirements for quarantine security. Systems approaches integrate biological, physical, chemical, and operational factors which can affect the incidence, viability and reproductive potential of a pest which together provide quarantine security.

The various components of the systems approach were described and its importance in evaluating overall security explained. Several examples of systems approaches currently in use were given. Future scientific data supporting the use of a systems approach will result in the eventual analysis of quarantine risk based on sound biological information regarding pest incidence in the commodity and its likelihood of occurring in commercially shipped fruits and vegetables.

Alternatives to Methyl Bromide as a Quarantine Treatment for Apples, Pears and Cherries

Harold R. Moffitt, USDA, ARS, FVIR, Yakima, WA

While the codling moth is the primary pest of quarantine concern on U. S.-produced apples, pears or cherries for export, the lesser appleworm, apple maggot, plum curculio, McDaniel spider mite, pear psylla, western cherry fruit fly, and the oriental fruit moth, among others, are also of quarantine concern. Most of our foreign markets rely on an inspection and certification procedure to meet quarantine requirements for these pests. However, a few require a direct treatment, particularly for codling moth. Among these are Japan and the Republic of Korea. Fumigation with methyl bromide has, in the past, generally been the quarantine treatment of choice.

Among the techniques being studied as possible alternatives for fumigation with methyl bromide for quarantine disinfestation are low temperatures, high temperatures, low oxygen atmospheres, irradiation, multicomponent treatments,

and a systems approach.

Exposure to low temperatures of 0.0 to 2.2°C, as commonly used in long term storage of apples and pears, will provide quarantine control of codling moth eggs and larvae but exposure periods as long as 90 days or more are required.

Preliminary research indicates that high temperatures of 40.0 to 50.0°C may be required to provide control of codling moth larvae. Low oxygen controlled atmospheres of 1.0 to 3.0% and 2.0 to 3.0% carbon dioxide may be a significant mortality factor for codling moth but only at higher temperatures.

Research has shown that irradiation at 200 Gy may provide quarantine control of codling moth eggs and larvae, based on prevention of development of adults capable of mating and reproducing. Selected combinations of temperature, low oxygen controlled atmospheres, or fumigation with methyl bromide also show potential as quarantine treatments.

A systems approach, incorporating production, harvest, and postharvest practices to preclude the presence of the codling moth in the packed box to be exported, also provides a high degree of quarantine security for codling moth in apples and cherries.

While a number of alternatives to fumigation with methyl bromide as a quarantine treatment for codling moth and other arthropod pests of U. S.-produced apples, pears, and cherries may be possible, few, if any, have the potential to be as broadly applied as methyl bromide. Further research is needed to determine which approaches will provide the degree of quarantine security needed for a given pest complex and a given fruit host.

RECOMMENDATION

1. Develop generic treatments for commodity-pest combinations to facilitate development and certification.

2. Develop alternative statistical methods for risk analysis and treatment efficacy.

3. Research must continue on systems approaches to meet quarantine security. Sound biological information will provide more flexibility in reducing either the severity or need for specific postharvest disinfestation procedures.

4. None of the alternatives discussed have the broad application of methyl bromide. Further research is needed to provide optimum utilization of these alternatives either alone or when combined.

MANAGEMENT OF PESTS IN LIEU OF TREATMENT

SUMMARY

Moderator: Nicanor J. Liquido, USDA, ARS, TFVRL, Hilo, HI

Pest management strategies may constitute suppression of pest populations to a level that the required quarantine security is met; simply put, pest suppression methods may be used in establishing certified infestation-free areas. Infestation-free areas may also be certified by establishing pest-free periods and infestation free hosts (variety or stage of maturity). Pest management strategies may also be aimed at reducing the infestation load of pests in commodities entering the packing houses for conventional quarantine treatments.

RECOMMENDATION

Improved planning and communication between ARS, APHIS, and other (state and foreign) regulatory agencies in developing management practices in lieu of treatment that fulfill quarantine security requirements.

Anastrepha ludens Infestation-Free Areas in Texas

Shashank S. Nilakhe, Texas Department of Agriculture, Austin, TX

The Mexican fruit fly, *Anastrepha ludens* (Loew) is a citrus pest of regulatory significance in Texas. Movement of citrus grown in Texas to other citrus-producing states is allowed only after application of either one of the following regulatory treatments: field application of malathion bait sprays, or a postharvest treatment using methyl bromide fumigation or cold (low, lethal temperature). In general, the Texas citrus industry does not employ any of these regulatory treatments, but instead uses a management strategy comprised of biological survey and releases of sterile flies as prescribed in the Federal Mexican Fruit Fly Protocol.

According to the current management strategy, Texas citrus can be shipped to all domestic markets in the United States without a conventional regulatory treatment provided that: (1) Mexican fruit flies are surveyed continually using McPhail traps at a density of five traps per square mile in the approved production areas; (2) at least 600 sterile adults are released per acre per week on all commercial citrus and peaches; and (3) no wild adults have been detected within one mile of a fruit harvest site. Detection of one wild Mexican

fruit fly adult will initiate a delimiting survey and an increase in sterile fly releases. A regulatory treatment is required when two or more wild adults are recovered within 30 days and within one mile of one another.

Anastrepha suspensa Infestation-Free Areas in Florida

Connie Riherd and Nguyen Ru, Florida Dept. of Agric. and Consumer Services, Gainesville, FL

James R. Brazzel, USDA, ARS, MPMC, Edinburgh, TX

The quarantine protocol that allows export of grapefruits and oranges from areas maintained free of Caribbean fruit fly, *Anastrepha suspensa* (Loew), infestations has two certification procedures. The first is based on negative trapping in the production area. The designated production area must be 120 ha, surrounded by a O.8 km buffer zone that is absolutely free of preferred, suitable host plants, and with more than 4.8 km distance from residential or other areas where numerous, preferred fruiting host plants occur. If host plants occur in the buffer area, they must be treated with a bait spray, i.e., 71.04 ml of 91% malathion and 284.16 ml of hydrolyzed protein per 0.4 ha, weekly. The area must have 15 McPhail traps per square mile with weekly servicing. A two-fly find within 2.4 km and within a 30 d period necessitates that a 2.4 km area around the site of detection be immediately withdrawn from the program. One fly find is not considered an indication of an existing infestation. For early season grapefruit (1 August-20 December), detection of three adults in McPhail traps results in withdrawal of certification. A previously certified area may be recertified if a 0.4 km area surrounding the fly find is treated with bait spray at 7-10 d intervals, 30 d prior to and during harvest, and that traps indicate a fly-free condition.

The second certification procedure is based on the application of bait sprays. The minimum size of the production area must be 16 ha with a 92.2 m buffer zone. The buffer area must not harbor any suitable host plants. The production area must be at least 0.8 km away from residential areas. Host plants within the production and buffer areas must be treated with a bait spray weekly. Traps must be established at a density of 15 traps per square mile, with a minimum of four traps. Aerial bait sprays consisting of a mixture of 71.04 ml of 91% malathion and 284.16 ml of hydrolyzed protein per 0.4 ha must be applied to the production area and the buffer zone beginning at 7 d before harvest and continued throughout the harvest period at 7-10 d intervals. Early season grapefruit may be certified following this procedure without

requiring the production area to be 0.8 km away from residential areas or areas with numerous preferred suitable hosts. A single fly find in areas that have been treated with bait sprays tantamounts to cancellation of the certification.

Relevance of Cultural Practices of Fruit Selection and Field Sanitation to Approved Heat Treatments For Papaya

Nicanor J. Liquido, USDA, ARS, TFVRL, Hilo, HI

Irrespective of variety and level of maturity, there are two certified heat treatments for papayas grown in Hawaii and destined for markets in the Mainland United States and Japan: vapor heat treatment and high temperature forced-air treatment (commonly referred to as hot air). The vapor heat treatment uses high-temperature water-saturated air to raise the pulp temperature up to 44.4°C. The hot air treatment, a modification of the vapor heat treatment, elevates the fruit core temperature up to 47.2°C using hot air with 40-60% RH.

Vapor heat and hot-air treatments are proven, efficacious commodity quarantine treatments against eggs and larvae or Mediterranean fruit fly (*Ceratitis capitata* [Wiedemann]), oriental fruit fly (*Bactrocera dorsalis* [Hendel]), and melon fly (*Bactrocera cucurbitae* [Coquillett]) in papaya fruits at all stages of maturity. However, packing house operators have been advised to select and treat only quarter ripe and less mature fruits. In addition, many papaya growers are enforcing the practice of field sanitation, which involves removal of ripe fruits on trees and on the ground. Intensive field studies conducted in commercial papaya growing orchards on the islands of Hawaii are the bases of the above self-imposed restrictions by the papaya industry. Results of these studies showed that: oriental fruit fly and melon fly infest papaya at all degrees of ripeness and that the densities of egg and larval infestations increase with the increase in fruit ripeness; the density of oriental fruit fly is much higher in fields where sanitation is not practiced; melon fly infestation was observed only in unsanitary fields.

By practicing strict fruit selection and field sanitation, heat-treated and packed fruits would have a low infestation load that may consequently result in a lower probability of federal and state inspectors and consumers finding fruits with dead eggs and fully-grown larvae. These practices may prevent unnecessary disruptions as was experienced in February, 1992 when dead larvae in vapor-heated papayas were found by state inspectors in California which resulted in temporary suspension of the vapor heat treatment for papaya.

Non-host Status, Pest- Free Zones, and Pest-Free Periods

Dr. Victoria Y. Yokoyama, USDA, ARS, HCRL, Fresno, CA

The walnut husk fly, *Rhagoletis completa* (Cresson), is used as an example for developing the concepts of pest-free zones, pest-free periods and non-host status. The walnut husk fly is a pest of regulatory concern in stone fruits exported to New Zealand where economic fruit flies do not occur. The quarantine strategy of a pest-free zone for walnut husk fly cannot be fulfilled in the San Joaquin Valley of California. New Zealand defines a pest-free zone as no infestations within 50 miles of the location where fruit is grown and packed.

The pest-free period has been documented for walnut husk fly in Merced, Madera, Fresno, Tulare and Kern counties by a trapping program using yellow sticky traps baited with ammonium carbonate. The pest-free period for the San Joaquin valley is described as the period between the beginning of stone fruit harvest in the spring and July 1 when the first adults emerge from pupae in the soil. The occurrence of a preovipositional period prior to egg laying will help ensure the validity of the pest-free period for walnut husk fly.

Laboratory choice and no-choice tests and field choice tests were conducted to determine the acceptability of peaches, nectarines and plums to oviposition and larval development. The results showed that plums were an unacceptable host, and peaches and nectarines were inadequate hosts compared to walnuts, the normal host.

We propose that plums can be shipped to New Zealand without quarantine treatment throughout the growing season and that peaches and nectarines can be shipped without quarantine treatment during the pest-free period.

PRODUCT QUALITY CONSIDERATIONS IN DEVELOPMENT OF QUARANTINE TREATMENTS

SUMMARY

Moderator: Alley E. Watada, USDA, ARS, Beltsville, MD

The quality of a commodity is a very significant and important factor in its marketability and consumer acceptability, thus maintenance of quality needs to be given utmost attention in development of pre- and postharvest handling conditions such as quarantine treatments. Effects of quarantine treatments on quality differ with commodity, cultivar, maturity and condition of commodity, and postharvest handling conditions/treatments. The effect may or may not be apparent immediately after treatment and the injury/damage symptoms of a treatment are not the same with all commodities. Research on development of quarantine treatments include the following:

- Identify physical, visual, chemical or physiological symptoms of injury or damage caused by quarantine treatments.

- Identify latent symptom development of injury or damage, particularly after simulated storage and marketing period.

- Identify physiological or biochemical changes that can be used as markers to determine early stages of injuries or damages, particularly of minor injury prior to symptom development.

- Develop kinetic models to correlate biochemical indices to damage.

- Determine physiological state/maturity when the commodity is most resistant or vulnerable to quarantine treatments.

- Determine the fundamental biochemical mechanism of injury or damage caused by quarantine treatments.

- Determine pre- or postharvest treatments such as conditioning or cold/hot treatments that may enhance resistance to quarantine treatments.

- Determine the fundamental mechanism of pre- or postharvest treatments that enhance resistance to quarantine treatments.

- Determine feasibility of promising quarantine treatments on diverse cultivars of a given commodity.

- Identify treatments such as modified atmosphere (film wrap or surface coating), controlled atmosphere, and calcium treatments which are known to maintain product quality and that would have a synergistic effect with other treatments on insect mortality.

Overview of Product Quality Consideration in Quarantine Treatments

Roy McDonald, USDA, ARS, Orlando, FL

During any handling or treatment subsequent to harvest, horticultural commodities can be damaged. This is particularly true when commodities are subjected to some quarantine treatments required for disinfestation purposes. It is important that quarantine treatments are efficacious but do not adversely affect the commodity's quality, condition, and susceptibility to decay. Any treatment that disinfests a commodity should have minimal deleterious effects on that commodity. Damage manifests itself as the loss of market quality attributes including shelf appearance, flavor, texture, aroma and increased susceptibility to decay organisms.

Individual commodities will respond differently to the physical and chemical stresses imposed by quarantine treatments. Deleterious commodity responses may be conspicuous and appear immediately following treatment or only will become apparent after a storage or marketing period and include abnormal weight loss, pulp softening, peel discoloration, surface lesions, and increased decay. Some responses will be physiological in nature occurring especially in those commodities that are mature at the time of treatment but, ripen after treatment. Symptoms of this response in these climacteric fruits include atypical peel or pulp color, nonuniform softening, abnormal texture, and off-flavors.

Developing a comprehensive and useful rating system that describes the characteristics of product condition based on physical and physiological parameters is important. The parameters for each characteristic should be well defined and documented both in the text and in photographs so examiners can systematically and accurately describe changes. Treated and untreated control fruit should be examined before and after treatment and after storage and/or simulated marketing conditions. Some characteristics are objectively or subjectively measured while others are determined both objectively and subjectively. The evaluation must provide for measurable resolution for specific characteristics and for changes in those characteristics being examined. In general, the results of an effective evaluation should furnish lucid indicators that

will provide sound conclusions to assist in developing recommendations.

Future research should include 1) physiological and biochemical basis of damage, 2) physiological basis of conditioning phenomenon, 3) pre- and postharvest treatments to reduce damage, 4) kinetic models to correlate biochemical indices to damage, and 5) Pre- or postharvest treatments which would reduce damage needs to be developed.

Some of the quarantine treatments have no deleterious effects on the condition and quality of some commodities and cultivars. However, injury can occur at times with approved treatments under commercial conditions. Research seeks to further refine the currently approved treatments and to develop alternatives.

Because consumers have become increasingly cautious about chemical treatments, substantial interest exists in physical treatments, especially the use of temperature management. It is important that treatments developed under laboratory conditions be feasible in a commercial setting. The treatment protocol must tolerate not only the variability in commodity condition, but also treatment variations which occur under commercial conditions without leading to commodity damage or insect survival.

CURRENT AND FUTURE ARS RESEARCH ON PRODUCT QUALITY AS AFFECTED BY QUARANTINE TREATMENTS

Thermal Process Calculations for Quarantine Heat Treatments at Hilo, HI

Harvey T. Chan, Jr., and Eric Jang, USDA, ARS, TFVRL, Hilo, HI

INTRODUCTION

Heat treatments are used as quarantine treatments to disinfest fruits of insects prior to shipment. Heat treatments have been developed for papayas (Couey and Hayes, 1986: Armstrong et al., 1989, Balock and Kozuma, 1954; Seo, et al., 1974), mangoes (Sharp and Spalding, 1984; Merino et al., 1985; Balock and Starr, 1945), and bananas (Armstrong, 1982). The development of heat treatments generally resulted from a series of empirical experiments on the efficacy of the treatments on the insects coupled with parallel experiments on the phytoxicity of host fruits. While such empirically developed treatments have been approved for quarantine treatments the treatments have occasionally produced fruit of poor quality. The deleterious effects of heat on fruit quality have been characterized in mangoes as spongy tissue (Esquerra et al., 1989), in papayas as hard lumpy fleshed fruits (Chan et al., 1986), and in cucumbers as surface pitting (Chan and Linse, 1989).

Thermoprocessing of canned and processed foods is an established field of science which transformed from empirical methods in the early 1900s to systematic methods employing thermokinetics of enzyme inactivation, thermoresistance of bacteria, and heat penetration or thermal conduction of the commodity. Thermal process evaluation as used by the food industry integrates the lethal effects of various time-temperature relationships to determine the adequacy of the heat process to ensure the safety of the product as well as minimize the over-processing to preserve the products organoleptic and nutritive properties (Stumbo, 1973). There is a need to develop thermoprocessing evaluation methods in the heat treatments of fruit to provide guidelines in the development of quarantine heat treatments and also to enhance product quality.

For papayas grown in Hawaii the main pests for which there are quarantine restrictions are the Mediterranean fruit fly,*Ceratitis capitata* (Weidemann), oriental fruit fly *Bactrocera dorsalis*, (Hendel), and melon fly, *B. cucurbitae* (Coquillet). The kinetics for the thermal death of the three fruit flies in egg and larval life stages has been determined in vitro in a water media (Jang, 1989). The heat penetration of papayas has been studied by Hayes (1984). The kinetics for heat tolerance has been described by Chan, 1985; 1990 using the

ethylene-forming enzyme (EFE) as a bioindicator of heat damage in papayas.

METHODS

Evaluation of heat treatments for kinetics of thermal death.
The first step in developing kinetic models of thermal death is the establishment of thermal death curves on a kinetic basis. This requires heating known quantities of the organism or enzyme activities at prescribed temperatures and times and quantifying the surviving organisms or enzymic activities. The kinetic approach differs considerably from the thermal death point or thermal death time (TDT) approach in describing thermal death. In the TDT method the final point of death is determined for each time and temperature wherein zero values (100% kill of organism or enzyme activity) are encountered for the particular organism or enzyme activity. In cases where thermal death follows algorithmic function then the TDT approach is valid only when the initial concentration of organism or activity is known or stated. Host microorganism and enzyme activities follow logarithmic thermal death or heat inactivation curves. Such logarithmic relationships follow what is termed first-order rate functions which is expressed as:

(Eg. 1.) $\quad \text{Log } S = -k/2.3\,(t) + \text{Log } S_O$

(Eq. 2.) $\quad$ or $kt = 2.3 \text{ Log } S_O/S$

where S_O = the initial concentration and S = the survivors or the remaining activity, t = time of heating, and k = the first-order reaction rate constant.

In the discussion of rates of thermal death a term other than k is referred to since k values are hard to visualize instead a term D-value is used which is easier to visualize since a D-value is defined as the time required to obtain 90% death at a particular temperature. The term D-value was coined from the fact that 90% death on a log plot traverses 1-log order, or 1-Decade. For example a plot that traversed from 100 to 10% or from 10 to 1% would traverse 1-log cycle and hence show 90% reduction or 1-decimal point reduction in numbers of survivors. The D-values are calculated from equation 2 where S_O = 100 and S = 10. Therefore kt = 2.3 log (100/10) then t = 2.3/k.

This time, t, is defined as D-value which describes the time required to reduce the number of survivors by 90%. Generally as the temperature of the heat treatment is increased the exposure time required to obtain kill or enzyme inactivation is decreased. Such effects of temperature on reaction rates, k, can be described mathematically by the Arrenhius Equation: (Eq. 3) $\text{Log } k_2/k_1 = E_a/2.3R\,(T_2\text{-}T_1/T_2T_1)$ where K_1 and K_2 = the 1^{st} order rate constant, k, at the absolute temperatures, T_1 and T_2, respectively. And E_a, = the Activation Energy, and R = 1.987 cal/deg-mole, the gas constant. The change in reaction rates with changes in reaction temperatures can also be expressed as 010

where:

(Eg. 4) $Q_{10} = k_2/k_1$ when $T_2 = T_1 + 10°C$

RESULTS

The thermal inactivation of the EFE system in papayas followed first-order kinetics. Therefore, equations 1 and 2 could be appropriately applied (Fig 1.). However in the case of the thermal death kinetics of oriental fruit fly larvae first-order kinetics was not applicable. Instead the equation

(Eq. 5) $t = (\log S_O - \log S)^a/k - c/k$

was found to accurately describe the thermal death of oriental third-instar larvae (Fig. 2). The Arrenhius plots as derived from Eq 1. for papaya EFE, and Eq. 5. for the oriental larvae are shown in figures 3 and 4, respectively.

Figure 5 depicts the relationship between treatment time and treatment temperature for oriental fruit fly eggs and larvae, papaya EFE, stemphylium a fruit pathogen. The D-values for insects was 3-D (99.9% kill) and for the papaya EFE system and for the fruit pathogen stemphylium it was 1-D-value (90%). The D-values for papaya EFE was from the most heat susceptible tissue (1/4-ripe mesocarp). Hence summarizes the effects of temperature on the three important factors (1) insect kill, (2) fruit tolerance, (3) postharvest decay that must be addressed when developing a quarantine heat treatment.

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2. Chan, H.T., Jr., 1991. The effects of ripeness and tissue depth on the heat inactivation of the ethylene-forming enzyme in papayas. J. Food Sci. 56: 996-998.

3. Jang, E.B., 1986. Kinetics of thermal death in eggs and first instars of three species of fruit flies (Diptera: Tephritidae). J. Econ. Entomol. 79: 700-705.

4. Jang, E.B., 1991. Thermal death kinetics and heat tolerance in early and late third instars of the oriental fruit fly(Diptera:Tephritidae). J. Econ. Entomol. 84: 1298-1303.

FIGURE LEGENDS

FIGURE 1- Heat inactivation of papaya EFE in 1/4-ripe mesocarp tissue at 47°C.

FIGURE 2- Thermal death curves of oriental third-instar larvae.

FIGURE 3- Arrenhius plot of the heat inactivation rate constants,k, of papaya EFE in 1/4-ripe mesocarp tissue.

FIGURE 4- Arrenhius plot of the thermal death rate constants, k, of eggs, feeding and popping third-instar oriental fruit fly.

FIGURE 5- Effects of temperature on 1)-values of: (1) oriental fruit fly eggs and larvae, (Z) papaya EFE system, (3) stemphylium fruit rot.

Figure 1.

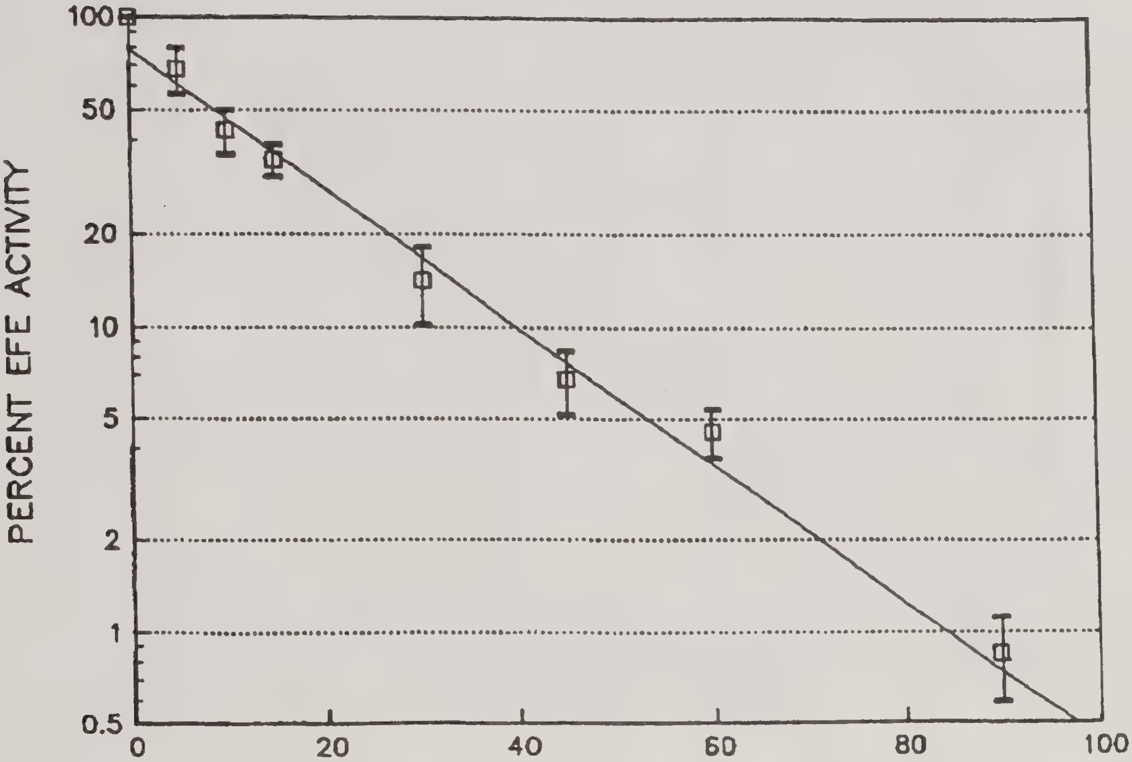


Figure 2.

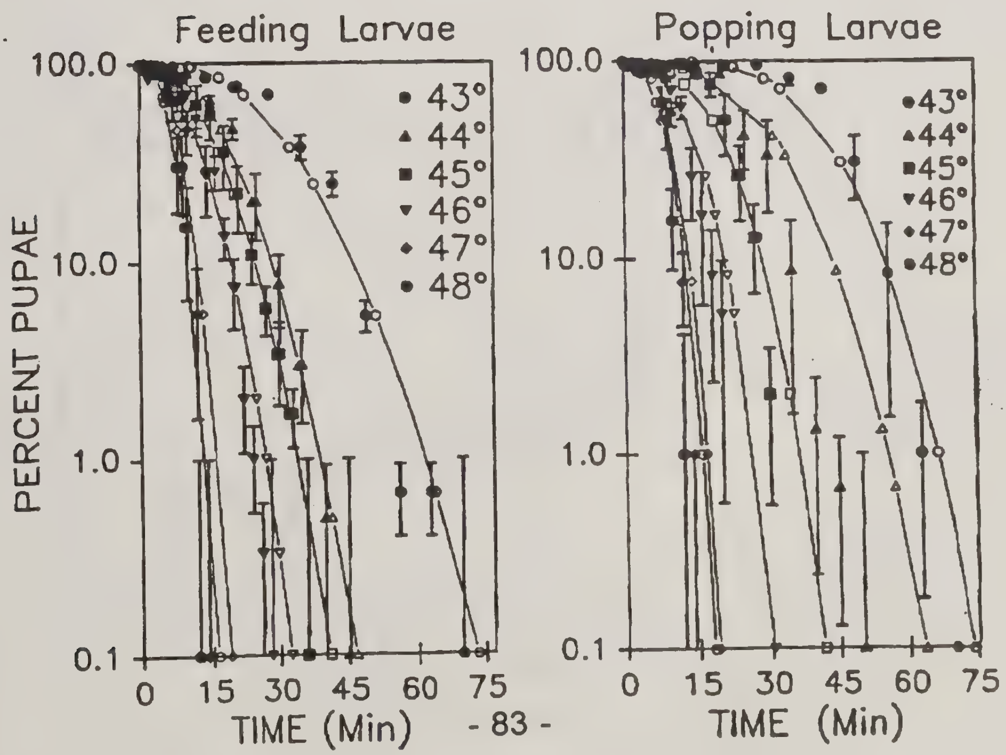


Figure 3.

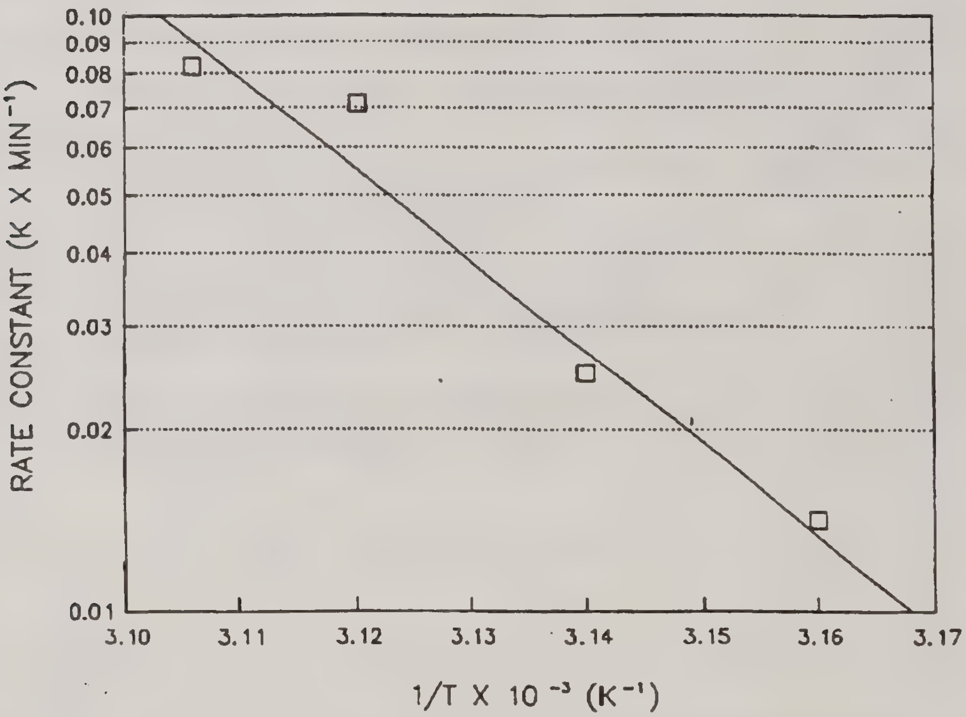


Figure 4.

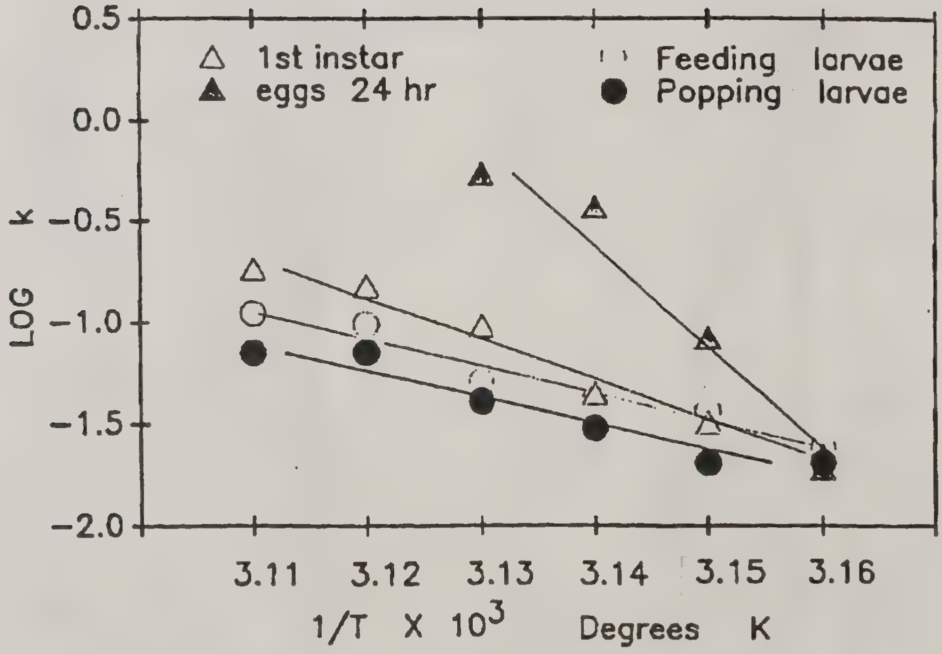
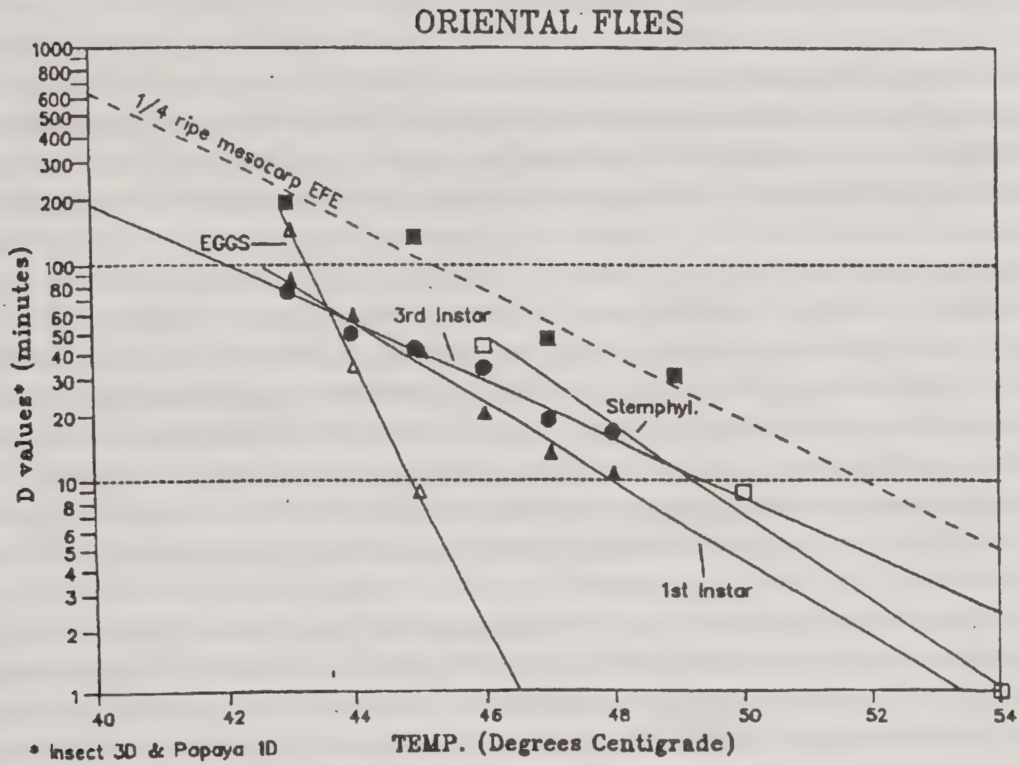


Figure 5.


ORIENTAL FLIES
1000
800
600
500
400
300
200
100
80
60
50
40
30
20
10
8
6
5
4
3
2
1
1/4 ripe mesocarp EFE
EGGS
3rd Instar
Stemphyl.
1st Instar
D values* (minutes)
40
42
44
46
48
50
52
54
TEMP. (Degrees Centigrade)
* Insect 3D & Papaya 1D

Current and Future Research at Fresno, California

Laurie G. Houck, USDA-ARS, Fresno, CA

Commodity insect quarantine treatment research has been conducted on fresh fruits and vegetables at the Fresno Horticultural Crops Research Laboratory since before the 1980-1982 Mediterranean Fruit Fly outbreak. Tests were conducted by Dr. John M. Harvey, Dr. Douglas J. Phillips and Dr. Joseph L. Smilanick on stone fruits, Mr. Joseph K. Stewart with lettuce, Dr. Werner J. Lipton with vegetables and Dr. Laurie G. Houck and Dr. Charles F. Forney with citrus. Harvey, Phillips, Stewart and Forney have retired or resigned. Smilanick continues work on stone fruit insect treatment problems and karnal bunt (a quarantine fungal disease) problems of wheat, Houck works on citrus and avocado insect treatment problems, and Mr. R. Tom Hinsch and C. Max Harris have participated in some nectarine studies, as has Dr. Victoria Yokoyama in the entomology group. This report is limited to phytotoxicity problems of citrus fruit to postharvest insect quarantine treatments.

Ethylene Dibromide fumigation was the quarantine treatment of choice for nearly all commodities because of its ease of use and relatively inexpensive facilities requirement, and was, therefore, the only treatment studied on citrus until ethylene dibromide was banned in 1985. Since that time (1) other fumigants, (2) tephritid fruit fly cold treatment (0-2.2°C for 10-24 days depending on exact temperature used and fruit fly species involved) and (3) hot water treatments for Fuller rose beetle control have been studied in the approximate ratio of 50% : 25% : 25%, respectively.

A series of tests with film-wrapped citrus fruit showed that films types and thicknesses are differentially permeable to the fumigants ethylene dibromide, hydrogen cyanide and methyl bromide. Each film type used to wrap fruit should be tested, at the fumigation temperatures that may be used, to ensure that the required quarantine dosage is attained inside the wrapped fruit. If necessary appropriate higher dosages of fumigant should be determined for use with each film type.

Several preliminary tests with hydrogen cyanide showed that citrus fruit were severely injured at dosages required to kill Fuller rose beetle eggs (efficacy tests were performed by Dr. Ed Soderstrom). Two tests with phosphine gas, at the long exposure times and high temperature required for phosphine, indicate that phosphine fumigation severely injures citrus fruit.

For the tests with cold treatment, hot water treatment and methyl bromide fumigation, fruit, mainly lemons and grapefruit but also some navel and Valencia orange tests, was collected from major geographic producing areas

(desert, coast and inland San Joaquin Valley), at different seasons (early, mid and late), of major economic maturity classes (yellow, silver, light green and dark green lemon peel color classes), and before or after ethylene degreening or washing, waxing and packing to determine fruit response to various treatments. Fruit injury threshold tolerances for the various cold, heat and methyl bromide fumigation treating conditions are being determined for the various, types of fruit and growing conditions mentioned above. Examples of data obtained so far were shown via numerous slides to the workshop attendees.

A short summary of data obtained so far follows. Citrus fruit vary greatly in susceptibility or tolerance to cold, heat and methyl bromide fumigation treatments by species, by season, by fruit maturity, and by packinghouse pretreatment or posttreatment handling procedures. Early season (hot weather) desert lemons and hot weather harvested grapefruit are severely injured by cold treatment but cold season fruit are not. Early season desert lemons are more tolerant of hot water treatments than are late season desert or coastal or valley lemons. Yellow and silver lemons are more sensitive to methyl bromide injury than light or dark green fruit. Lemons methyl bromide-treated after wash/wax procedures were injured less than similar fresh-picked fruit treated before washing or waxing. curing fruit for 1 week at 15-C before any of the above treatments reduced injury as compared to uncured fruit. Long aeration (up to 24 hrs.) after methyl bromide fumigation and before cold storage almost markedly reduced methyl bromide injury to fruit. If fruit from a specific geographic area or maturity or species are sensitive to one of the above treatments they may be tolerant of another treatment. That earlier treatment may itself be injurious to other fruit at another time of year or maturity. A schedule of acceptable or unacceptable treatments for fruit of different geographic areas, maturities, species, etc., is being prepared.

Future research plans are to phase out the methyl bromide fumigation research because of its probable international phaseout due to the ozone problem. We will complete research in areas that have been incompletely studied. Studies on curing or preconditioning fruit before quarantine treatment so that fruit may withstand harsher treating conditions will be expanded. Physiological and biochemical investigations on the cause(s) of citrus responses to quarantine treatments are planned in conjunction with Dr. Lewis H. Aung at this station.

Current and Future Research at Weslaco, Texas

Dr. Krista C. Shellie, USDA-ARS, Weslaco, TX

Our quarantine research at Weslaco is focused on development of non-chemical quarantine treatments for disinfestation of *Anastrepha ludens*. I work cooperatively with Dr. Robert Mangan and Mr. Sam Ingle in developing quarantine treatments. Bob and Sam handle the entomological aspects and I evaluate phytoxicity. The majority of our research has been directed towards the use of heated, forced moist-air as a quarantine treatment. Moist air is distinguished from vapor heat because dew point is maintained 2°C below fruit surface temperature, preventing condensation of water on the surface of the fruit.

I think most of the people in this room are familiar with this experimental forced air chamber. It was designed by J. Gaffney, who used to be with the ARS. We have been researching the potential of hot forced moist-air as quarantine treatment for citrus- including grapefruit, tangerine, and oranges, and for mangoes. Because much of our work deals with import crops and we have rearing capabilities for *A. ludens*, we have developed a treatment protocol that minimizes the amount of fruit required, and is liberal in the amount of larvae that is needed. We evaluate phytotoxicity at 2 steps during the develop of new treatment protocols, during fruit tolerance tests and during confirmatory fruit quality tests. These steps are identified in Figure 1. Based on previous knowledge of larval physiology, we select various temperatures and doses near the physiological limits of larvae for the fruit tolerance tests. So, during the fruit tolerance tests, we subject the fruit to multiple temperatures near the physiological limits of larvae.

We store control fruit at 20°C while other fruit is being treated. To control for physiological changes in the fruit during the experiment we use a randomized block design. That is, we complete the first replication of each treatment prior to treating replication 2. We size grade the fruit because small fruit heat faster and are, therefore, more susceptible to phytotoxicity. And we store the fruit after treatment to evaluate whether the treatment has any affect on shelf life. We evaluate fruit quality traits directly after treatment and at regular intervals during storage. The traits we consider include color (internal and external), firmness, soluble solids, sugars, weight loss, titratable acidity, organoleptic traits, and incidence of decay.

The main objective of the fruit tolerance tests is to compare the quality of control fruit to the quality of heat treated fruit. For example, partial results from fruit tolerance tests for 'Dancy' tangerine at 45°C and 48°C appear in Table 1. At 45°C, the flavor of heat treated fruit was rated similar to the flavor of control

fruit. However, the flavor of fruit that was heated for 2 h at 48°C was rated significantly inferior to the flavor of control fruit. If 100% larval mortality cannot be accomplished within 2 h at 48°C, a cooler temperature is required to avoid phytotoxicity.

The heating rate at the center of the fruit generated during the fruit tolerance tests was simulated in variable temperature water baths containing naked larvae to estimate percentage larval mortalities. The variable temperature water baths were also developed by J. Gaffney. Results from naked larval mortality tests for 'Dancy' tangerine indicated that 100% mortality will be achieved in large fruit after a 4h treatment at 45°C. However, at least 2 h is needed at 48°C for large fruit to achieve 100% mortality. Due to phytotoxicity problems, 48°C is not a desirable temperature, and 45°C was chosen for efficacy tests and confirmatory fruit quality tests.

In summary, the current research activities in Weslaco include; fruit tolerance and confirmatory tests for hot forced air treatment for 'Dancy' tangerine, fruit tolerance tests for hot forced air treatment for 'Valencia' oranges, and confirmatory quality tests for hot forced air and hot water dipped for mango. Our future plans include: confirmatory fruit quality tests for hot forced air treatment in grapefruit, monitoring fruit quality in commercial scale hot forced air treatment facilities, and investigating the affect of fruit heating rates on fruit quality.

Table 1. Results of 'Dancy' Tangerine Fruit Tolerance Tests

TEMP-HR	FLAVOR	TASTE	SSC	WT. LOSS
Control	3.6a	0.55a	8.7a	0.51a
45 C -1	3.6a	0.52ab	8.6a	0.44b
2	3.6a	0.50ab	8.6a	0.73c
3	3.4a	0.48b	8.7a	0.86d
4	3.4a	0.42c	8.5a	1.16e
MSE(df)	1.19(574)	0.02(162)	0.32(162)	0.03(99)
Control	3.7a	0.62a	8.8a	0.51a
48 C -1	3.6a	0.57ab	8.7ab	0.32b
2	3.0b	0.52b	8.6b	0.72c
3	3.0b	0.54b	8.7ab	0.85d
4	2.6c	0.50b	8.6ab	1.07e
MSE(df)	1.05(557)	0.02(178)	0.24(178)	0.02(99)

Current and Future Research at Orlando, Florida

William R. Miller, USDA, ARS, Orlando, Florida

The Export and Market Improvement Management Unit of the U.S. Horticultural Research Laboratory at Orlando has 1.5 SYs engaged in the evaluation of horticultural commodities relative to the development of quarantine treatments to provide security against the Caribbean fruit fly *Anastrepha suspensa* (Loew). Investigations are designed to determine the tolerance of commodities to stresses encountered during treatment. We may develop specific treatments or systems that will allow commodities to be exposed to time and temperatures that will provide quarantine security and at times conduct confirmatory tests to determine physiological and physical tolerances. Experiments are also conducted to determine the effectiveness of pretreatment temperature manipulations that may alleviate damage that may otherwise occur during a particular treatment. Treatments used include high- or low-temperature air or water, gibberellic acid or irradiation, or combinations. We have computer controlled test facilities to conduct high temperature forced air, vapor heat or hot water treatments.

Investigations are primarily initiated and conducted within our management unit, but we also cooperate with USDA researchers at other locations including Miami, Winter Haven, and Gainesville, and with state researchers located at Lake Alfred and Gainesville, Florida. The following brief summary gives an overview of some past and current investigations and future research plans for the next several years at Orlando.

PAST, CURRENT AND FUTURE RESEARCH:

1. Grapefruit--cold treatment/vapor heat/hot water/gibberellic acid.

   a. During the early 1980s methods and the protocol for using the cold treatment on grapefruit were developed, along with the recommended application of temperature conditioning (7 days at 15°C) prior to cold treatment. This is the only practical quarantine treatment approved for use on grapefruit that are harvested from uncertified fly-free zones. The potential for a shorter-time/higher-temperature (3 days at 31°C) conditioning as an alternative regime to the longer-time temperature conditioning (7 days at 15°C) in reducing chilling injury during cold-treatment regimes was studied with negative results.

   b. Grapefruit ('Ruby Red' and 'Marsh') harvested early, mid or late in the season were vapor heat-treated (43.5°C for about 4.5 hours) and were not injured during treatment or after 5 weeks of storage. However

grapefruit treated with water immersion (46°C for 4 hr) were injured.

c. Extensive field testing will continue to determine the effect of gibberellic acid to enhance the resistance of peel puncture by ovipositing flies. Experiments will continue to determine if grapefruit treated with gibberellic acid before harvest, and harvested throughout the season, are injured during conditioning (7 days at 15°C) and cold-treatment (19 days at 1°C), vapor heat or hot water, and irradiation, and after subsequent storage for 5 weeks.

2. Mangoes ('Tommy Atkins') were treated with heated forced air at 51.7°C for 125 min without injury, but 'Keitt' mangoes were severely injured and would not ripen normally. Future research is planned to test if heated air at 48°C until core temperature reaches 46.5°C causes injury to 'Tommy Atkins' and assess the potential of temperature conditioning as a method to reduce injury in 'Keitt' mangoes during heated air or heated water immersion tests.

3. Carambolas cold treated at 1°C for 15 days resulted in some injury, and conditioning at 3 or 7 days at 15°C provided little alleviation of injury. Plastic film wrapping was effective in reducing injury from cold treatment in one experiment but not in another. Heated water and air at 47, 48, or 49°C for 90, 120, or 150 min caused injury to peel. We will investigate methods such as antitoxicant coatings and time/temperature-conditioning regimes to reduce surface injuries and discoloration during low- or high-temperature treatments and investigate the effect of degreening carambolas before cold treatment.

4. Blueberries ('Climax') were severally injured by irradiation (gamma or electron) at dosages above 1.0 KGy. These experiments will be continued to determine the effect of low dosage irradiation as a quarantine treatment or as an alternative to methyl bromide.

Current and Future Research at Miami, Florida

Dr. Raymond McGuire, USDA-ARS, Miami, FL

Research has centered on mangoes, avocados, guavas, carambolas, papayas, and grapefruit, but in the last year the boniato, has been studied, as has golden apple, *Spondias cytherea*. The primary pest of concern has been Caribbean fruit fly, *Anastrepha suspensa*; however, recent work has included sweet potato weevil and banana moth. Although there continues to be some work with methyl bromide, fruit are now treated primarily with heat and cold, irradiation,

and fruit coatings that may create modified atmospheres.

Mangoes and grapefruits have been tested to determine their tolerance to hot water immersion and forced hot air treatment. Within this tolerance range, a treatment that kills the target pest can be selected. Mango is relatively resistant to heat, and constant temperature hot water immersion at 45°C for 90-115 min is a rapid treatment and effectively kills the fungus that causes anthracnose. Hot air treatment to 48°C is tolerated. It is longer and less effective for disease control. Grapefruit do not tolerate constant temperature hot water immersion at 48°C for 2 hr - the time needed for fruit fly contol, but a gradual increase to this temperature over 3 hr is much less damaging. Hot air treatment is preferable, however, for 3 hr at 48°C. By pretreating the fruit at 27 or 32°C for 12 hr before hot air treatment, damage, primarily an increased susceptibility to the fungal pathogen *Penicillium digitatum*, can be further reduced.

Heat and other quarantine treatments drastically reduce surface populations of beneficial microorganisms that may antagonize pathogens with which fruit may become inoculated in storage. These populations can drop from 10^5 colony forming units (cfu) /cm^2 to 10^1. By reapplying a yeast to the grapefruit in various citrus coatings after hot air treatment decay can be reduced. Although many coatings contain a solvent toxic to the yeast, a USDA product using methyl cellulose in water may actually support higher population levels. This coating is also being tested for its effect on fruit flies within fruit. The coating may alter the concentrations of gases within fruit, acting similar to storage in modified atmospheres. In combination, application of the coating may allow the use of less extreme heat or cold treatments for insect eradication.

Appendix A

Cross Reference of Common and Scientific Names of Pests in this Report

Pests Listed by Scientific Name

Scientific name	Common name
Anastrepha ludens (Loew)	Mexican fruit fly
Anastrepha obliqua (Macquart)	West Indian fruit fly
Anastrepha serpentina (Wiedemann)	serpentine fruit fly
Anastrepha suspensa (Loew)	Caribbean fruit fly
Asynonychus godmani Crotch	Fuller rose beetle
Bactrocera cucurbitae (Coquillet)	melon fly
Bactrocera dorsalis (Hendel)	Oriental fruit fly
Bactrocera latifrons (Hendel)	Malaysian fruit fly
Botrytis cinerea Pers. ex Fr.	gray mold
Cacopsylla pyricola Foerster	pear psylla
Ceratitis capitata (Wiedemann)	Mediterranean fruit fly
Colletotrichum gloeosporioides Penz.	anthracnose
Conotrachelus nenuphar (Herbst)	plum curculio
Cydia pomonella (Linnaeus)	codling moth
Cylas formicarius elegantulus (Summers)	sweet potato weevil
Diplodia natalensis Evans	stem end rot
Frankliniella occidentalis (Pergande)	western flower thrips
Grapholita molesta (Busck)	Oriental fruit moth
Grapholita prunivora (Walsh)	lesser appleworm
Lasioderma serricorne (Fabricus)	cigarette beetle
Mayetiola destructor (Say)	Hessian fly
Monolinia fructricola (Wint.) Honey	brown rot
Opogana sacchari (Bojer)	banana moth
Penicillium digitatum Sacc.	green mold
Platynota stultana (Walshingham)	omnivorous leaf roller
Rhagoletis completa Cresson	walnut husk fly
Rhagoletis indifferens Curran	western cherry fruit fly
Tetranychus mcdanieli McGregor	McDaniel spider mite
Thrips palmi Karny	melon thrips
Toxotrypana curvicauda Gerstaecker	papaya fruit fly

Cross Reference of Common and Scientific Names of Pests in this Report (cont'd)

Pests Listed by Common Name

Common name	Scientific name
anthracnose	*Colletotrichum gloeosporioides* Penz.
banana moth	*Opogana sacchari* (Bojer)
brown rot	*Monolinia fructricola* (Wint.) Honey
Caribbean fruit fly	*Anastrepha suspensa* (Loew)
cigarette beetle	*Lasioderma serricorne* (Fabricus)
codling moth	*Cydia pomonella* (Linnaeus)
Fuller rose beetle	*Asynonychus godmani* Crotch
gray mold	*Botrytis cinerea* Per. ex Fr.
green mold	*Penicillium digitatum* Wehmer
Hessian fly	*Mayetiola destructor* (Say)
lesser appleworm	*Grapholita prunivora* (Walsh)
Malaysian fruit fly	*Bactrocera latifrons* (Hendel)
McDaniel spider mite	*Tetranychus mcdanieli* McGregor
Mediterranean fruit fly	*Ceratitis capitata* (Wiedemann)
melon fly	*Bactrocera cucurbitae* (Coquillet)
melon thrips	*Thrips palmi* Karny
Mexican fruit fly	*Anastrepha ludens* (Loew)
omnivorous leaf roller	*Platynota stultana* (Walshingham)
Oriental fruit fly	*Bactrocera dorsalis* (Hendel)
Oriental fruit moth	*Grapholita molesta* (Busck)
papaya fruit fly	*Toxotrypana curvicauda* Gerstaecker
pear psylla	*Cacopsylla pyricola* Foerster
plum curculio	*Conotrachelus nenuphar* (Herbst)
stem end rot	*Diplodia natalensis* P. Evans
sweet potato weevil	*Cylas formicarius elegantulus* (Summers)
walnut husk fly	*Rhagoletis completa* Cresson
West Indian fruit fly	*Anastrepha obliqua* (Macquart)
western flower thrips	*Frankliniella occidentalis* (Pergande)
western cherry fruit fly	*Rhagoletis indifferens* Curran

Appendix B

PROGRAM

USDA, Agricultural Research Service
Quarantine Workshop for Horticultural Commodities
Marriott's Tenaya Lodge, Fish Camp, CA
September 15-16, 1992

REGISTRATION

Monday, September 14, 1992	1600 - 1900 - Lobby Lounge
Tuesday, September 15, 1992	0730 - 0800 - Foyer outside Salon III
	1000 - 1015
	1500 - 1515
	1700 - 1715
Wednesday, September 16, 1992	0745 - 0800 - Foyer outside Salon III
	1000 - 1015

MONDAY, SEPTEMBER 14, 1992

1830 - 2000 No-host mixer - Lobby Lounge

TUESDAY, SEPTEMBER 15, 1992 - Salon III

A. PLENARY SESSION (0800 - 0830)

Moderator: Dr. Jennifer Sharp, Research Leader, USDA, ARS, Miami, FL
(Alternate: Dr. Victoria Yokoyama, USDA, ARS, Fresno, CA)

0800 - 0810 Introduction and Announcements, Dr. Jennifer Sharp
(Alternate: Dr. Victoria Yokoyama)

0810 - 0820 Welcoming Address, Dr. Robert Reginato, USDA, ARS, Pacific West Area Director, Albany, CA

0820 - 0930 Workshop Charge/Objectives, Dr. Kenneth Vick, USDA, ARS, National Program Leader, Product Losses and Quarantine, Beltsville, MD

B. INDUSTRY INVOLVEMENT

Moderator: Dr. Eric Jang, Research Entomologist, USDA, ARS, Hilo, HI

0830 - 0850 Mr. David Miller, Director, Export Market Development, California Tree Fruit Agreement, Sacramento, CA, "Mexico's Stonefruit Workplan Development - Industry's Perspective"

0850 - 0910 Mr. Craig Campbell, Director of Research and Development, J. R. Brooks and Son., Inc., Homestead, FL, "Involvement in South Florida's Fruit Industry" (Alternate: Mr. Ron T. Anderson, Director, International Market Development Committee, The National Hay Association, Ellensburg, WA, "Plant Quarantine Issues in the Hay Industry"

0910 - 1000 Discussion/Recommendations

1000 - 1015 BREAK

1015 - 1030 Discussion/Recommendations

C. STATISTICAL APPROACHES

Moderator: Mr. Victor Chew, Statistician, USDA, ARS, Gainesville, FL

1030 - 1100 Mr. Bruce Mackey, Statistician, USDA, ARS, Albany, CA, "Statistics in Quarantine Treatments"

1100 - 1145 Discussion/Recommendations

1145 - 1300 LUNCH

D. ARS/APHIS/OTHER AGENCY INTERACTIONS

Part I. Moderator: Dr. Norman Leppla, Director, Methods and Development, USDA, APHIS, Hyattsville, MD

1300 - 1330 Mr. Joe Vorgetts, USDA, APHIS, Hyattsville, MD, "Permit Procedures Overview"

1330 - 1350 Mr. Jim Fons, USDA, APHIS, Hyattsville, MD, "Quarantine Treatment Certification Process"

1350 - 1410	Mr. David Lüscher, California Department of Food and Agriculture, Sacramento, CA, "Federal Phytosanitary Certification, State and County Participation"
1410 - 1430	Dr. Robert Mangan, Research Leader, USDA, ARS, Weslaco, TX, "ARS Research in International Quarantine Programs"
1430 - 1500	Discussion/Recommendations
1500 - 1515	BREAK
Part II.	Moderator: Dr. Victoria Yokoyama, Research Entomologist, USDA, ARS, Fresno, CA
1515 - 1530	Dr. Jennifer Sharp, "ARS Quarantine Research Overview" (Alternate: Dr. Kenneth Vick)
1530 - 1545	Dr. Victoria Yokoyama, "Exports to Pacific Rim Countries"
1545 - 1600	Dr. Robert Mangan, "North American Free Trade Agreements"
1600 - 1615	Dr. Walter Gould, Research Entomologist, USDA, ARS, Miami, FL, "Caribbean Basin Initiative" (Alternate: Dr. Roy McDonald, Research Leader, USDA, ARS, Orlando, FL)
1615 - 1700	Discussion/Recommendations

WEDNESDAY, SEPTEMBER 16, 1992 - Salon III

E. METHYL BROMIDE

Moderator:	Dr. Patrick Vail, Laboratory Director, USDA, ARS, Fresno, CA
0800 - 0830	Mr. R. Franklin Handy, Great Lakes Chemical, Sacramento, CA, "Production and Uses"
0830 - 0900	Dr. Tom Duafala, TRICAL, Hollister, CA, "The Ozone Issue"
0900 - 0930	Mr. Robert Berninger, USDA, APHIS, Iloboken, NJ, "Quarantine Issues of Methyl Bromide, Present and Future"
0930 - 1000	Discussion/Recommendations
1000 - 1015	BREAK

F. ALTERNATIVE TREATMENTS

Moderator:	Dr. Guy Hallman, Research Entomologist, USDA, ARS, Miami, FL (Alternate: Dr. Harvey Chan, Research Leader, USDA, ARS, Hilo, HI)
1015 - 1030	Dr. Guy Hallman, "Tropicals, Subtropicals, Ornamentals" (Alternate: Dr. Victoria Yokoyama)
1030 - 1045	Dr. Victoria Yokoyama, "Stonefruits/Tree Nuts/Grapes"
1045 - 1100	Dr. Hal Moffitt, Research Entomologist, USDA, ARS, Yakima, WA, "Apples/Pears/Cherries"
1100 - 1145	Discussion/Recommendations
1145 - 1300	LUNCH

G. MANAGEMENT IN LIEU OF TREATMENT

Moderator:	Dr. Nicanor Liquido, Research Entomologist, USDA, ARS, Hilo, HI
1300 -1310	Dr. Shashank Nilakhe, Texas Department of Agriculture, Austin, TX, "Texas"
1310 - 1320	Dr. Connie Riherd, Assistant Director, Florida Division of Plant Industry, Gainesville, FL, "Florida"
1320 - 1330	Dr. Nicanor Liquido, "Hawaii"
1330 - 1340	Dr. Victoria Yokoyama, "Non-host Status/Pest Free Zones and Periods"
1340 -1415	Discussion/Recommendations

H. PLANT PATHOLOGY/PHYTOTOXICITY

Moderator:	Dr. Alley E. Watada, Research Leader, USDA, ARS, Beltsville, MD
1415 - 1445	Dr. Roy McDonald, "Overview of Product Quality, Consideration in Quarantine Treatments"
1445 - 1500	BREAK

Current and Future Research on Product Quality as Affected by Quarantine Treatments at Different Locations (15 minutes/person)

1500 -1515	Hawaii	Dr. Harvey Chan, Research Leader, USDA, ARS, Hilo, HI
1515 - 1530	Fresno	Dr. Laurie Houck, Research Plant Pathologist, USDA, ARS, Fresno, CA
1530 - 1545	Weslaco	Dr. Krista Shellie, Research Plant Physiologist, USDA, ARS, Weslaco, TX
1545 - 1600	Orlando	Mr. Bill Miller, Agricultural Marketing Specialist, USDA, ARS, Orlando, FL
1600 - 1615	Miami	Dr. Raymond McGuire, Research Plant Pathologist, ARS, Miami, FL
1615 - 1645	Discussion/Recommendations	

I. NPS COMMENTS (1645 - 1700)

J. STEERING COMMITTEE MEETING (1700 - 1730)

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Dr. Robert Mangan
Research Leader

Dr. Krista Shellie
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Appendix D

Prior to the 1992 Quarantine Workshop for Horticultural Commodities a poll was taken of ARS scientists involved in quarantine research. Each scientist was asked for the estimated portion of their time in the 1992 fiscal year that was dedicated to various aspects of their work. They submitted answers detailing the time spent on each of these categories:

- treatments or aspects of quarantine research investigated
- species of pests investigated
- types of commodities investigated

The results are presented in tabular and graphic form in this section. The unit for these tables and graphs is the **scientist year (SY)**. 100% of a scientist's work year = 1 scientist year.

Table I - shows ARS's SY commitment to quarantine research at each ARS facility involved in quarantine research.

Table II - details ARS's SY commitment to quarantine research by outlining each scientist's SY commitment to various treatments or aspects of quarantine research, pests, and commodities. The data is presented by location and location totals may be found at the bottom of the data for each location.

Figure I,
Figure II,
Figure III - are bar graphs showing SY's committed by location to each of the three categories with a bar graph for each of the eight ARS locations involved in quarantine research.

Figure IV,
Figure V,
Figure VI - are bar graphs displaying ARS's total SY commitment to one of the three categories.

Table I

Total Scientist Year's (SY's) in Quarantine Research at each ARS Laboratory

(Total Quarantine Research SY's for all locations = 20.28)

Scientist	SY
Fresno, CA.	
C. Curtis	0.50
L. Houck	1.00
J. Smilanick	1.00
E. Soderstrom	0.50
V. Yokoyama	1.00
Total SY:	**4.00**
Gainesville, FL.	
C. Calkins	0.90
P. Greany	0.50
Total SY:	**1.40**
Hilo, HI.	
J. Armstrong	0.90
H. Chan, Jr.	1.00
E. Jang	0.25
N. Liquido	0.25
Total SY:	**2.40**
Miami, FL.	
W. Gould	1.00
G. Hallman	1.00
J. Hansen	1.00
M. Hennessey	1.00
J. King	1.00
R. McGuire	0.80
J. Sharp	1.00
Total SY:	**6.80**

Scientist	SY
Orlando, FL.	
R. McDonald	0.50
W. Miller	1.00
W. Schroeder	0.25
Total SY:	**1.75**
Weslaco, TX.	
S. Ingle	1.00
R. Mangan	0.50
K. Shellie	0.33
Total SY:	**1.83**
Winter Haven, FL.	
P. Shaw	0.10
Total SY:	**0.10**
Yakima, WA.	
H. Moffitt	1.00
L. Neven	1.00
Total SY:	**2.00**

Table II

ARS Manpower in Scientist Years (SY) Allocated to Quarantine Research

Fresno, CA.

Scientist: L. Houck

Treatment or aspect	SY	Pest	SY	Commodity	SY
Commodity damage	1.00	NA	0.00	citrus	0.75
				avocado	0.25
Total SY:	**1.00**		**0.00**		**1.00**

Scientist: J. Smilanick

Treatment or aspect	SY	Pest	SY	Commodity	SY
Heat	1.00	gray mold	0.33	citrus	0.25
		green mold	0.33	stone fruits	0.75
		brown rot	0.33		
Total SY:	**1.00**		**1.00**		**1.00**

Scientist: E. Soderstrom

Treatment or aspect	SY	Pest	SY	Commodity	SY
Heat	0.25	Fuller rose beetle	0.10	citrus	0.10
Modified atmosphere	0.25	codling moth	0.40	walnuts	0.40
Total SY:	**0.50**		**0.50**		**0.50**

Scientist: C. Curtis

Treatment or aspect	SY	Pest	SY	Commodity	SY
Host status/resistance	0.50	codling moth	0.50	walnuts	0.50
Total SY:	**0.50**		**0.50**		**0.50**

Scientist: V. Yokoyama

Treatment or aspect	SY	Pest	SY	Commodity	SY
Chemical	0.30	Hessian fly	0.50	stone fruits	0.50
Cold	0.10	codling moth	0.10	hay	0.40
Heat	0.10	Oriental fruit moth	0.05	grapes	0.10
Host status/resistance	0.10	omnivorous leaf roller	0.05		
Pest-free period	0.10	walnut husk fly	0.20		
Inspection	0.10	western flower thrips	0.05		
Commodity damage	0.10	cigarette beetle	0.05		
Pressure	0.10				
Total SY:	**1.00**		**1.00**		**1.00**
Location Total SY:	**4.00**		**2.99**		**4.00**

Table II (cont'd)

ARS Manpower in Scientist Years (SY) Allocated to Quarantine Research

Gainesville, FL.

Scientist: P. Greany

Treatment or aspect	SY	Pest	SY	Commodity	SY
Giberellic acid	0.50	Caribbean friut fly	0.80	citrus	1.00
		Mexican fruit fly	0.10		
		Mediterranean fruit fly	0.10		
Total SY:	**0.50**		**1.00**		**1.00**

Scientist: C. Calkins

Treatment or aspect	SY	Pest	SY	Commodity	SY
Acoustical detection	0.10	Caribbean fruit fly	0.33	citrus	1.00
Irradiation	0.10	Mexican fruit fly	0.33		
Pest-free zone	0.10	Mediterranean fruit fly	0.33		
Sterile insect technique	0.30				
Parasitoids	0.20				
Giberellic acid	0.10				
Total SY:	**0.90**		**1.00**		**1.00**

Location Total SY:	**1.40**	**2.00**	**2.00**

Table II (cont'd)

ARS Manpower in Scientist Years (SY) Allocated to Quarantine Research

Hilo, HI.

Scientist: N. Liquido

Treatment or aspect	SY	Pest	SY	Commodity	SY
Host status/resistance	0.13	Mediterranean fruit fly	0.25	avocado	0.08
Heat	0.13	Oriental fruit fly	0.25	papaya	0.08
		melon fly	0.25	citrus	0.08
		Malaysian fruit fly	0.25		
Total SY:	**0.26**		**1.00**		**0.24**

Scientist: E. Jang

Treatment or aspect	SY	Pest	SY	Commodity	SY
Heat	0.10	Mediterranean fruit fly	0.25	papaya	0.10
Host status/resistance	0.05	Oriental fruit fly	0.25	avocado	0.10
Shrinkwrap	0.10	melon fly	0.25	misc. fruits	0.05
		Malaysian fruit fly	0.25		
Total SY:	**0.25**		**1.00**		**0.25**

Scientist: J. Armstrong

Treatment or aspect	SY	Pest	SY	Commodity	SY
Heat	0.30	Mediterranean fruit fly	0.25	avocado	0.10
Cold	0.30	Oriental fruit fly	0.25	atemoya	0.10
Commodity damage	0.20	melon fly	0.25	hot pepper	0.15
Host status/resistance	0.10	Malaysian fruit fly	0.25	citrus	0.10
				cucumber	0.05
				litchi	0.10
				mango	0.10
				papaya	0.10
				carambola	0.10
				misc. fruits	0.10
Total SY:	**0.90**		**1.00**		**1.00**

Scientist: H. Chan, Jr.

Treatment or aspect	SY	Pest	SY	Commodity	SY
Commodity damage	0.25	Mediterranean fruit fly	0.13	avocado	0.25
Heat	0.25	Oriental fruit fly	0.13	papaya	0.25
Cold	0.25	melon fly	0.13		
Post-treatment pathology	0.25	Malaysian fruit fly	0.13		
Total SY:	**1.00**		**0.52**		**0.50**

Location Total SY:	**2.41**		**3.52**		**2.00**

Table II (cont'd)

ARS Manpower in Scientist Years (SY) Allocated to Quarantine Research

Miami, FL.

Scientist: M. Hennessey

Treatment or aspect	SY	Pest	SY	Commodity	SY
Population biology	0.25	Caribbean fruit fly	0.80	avocado	0.25
Host status/resistance	0.25	Other *Anastrepha* sp.	0.20	mango	0.25
Monitoring	0.20			guava	0.10
Rearing	0.20			misc. fruits	0.40
Parasitoids	0.05				
Chemical	0.05				
Total SY:	**1.00**		**1.00**		**1.00**

Scientist: J. King

Treatment or aspect	SY	Pest	SY	Commodity	SY
Chemical	0.30	Caribbean fruit fly	1.00	citrus	0.20
Irradiation	0.30			mango	0.30
Heat	0.20			carambola	0.20
Coating	0.10			guava	0.20
Host status/resistance	0.10			misc. fruits	0.10
Total SY:	**1.00**		**1.00**		**1.00**

Scientist: R. McGuire

Treatment or aspect	SY	Pest	SY	Commodity	SY
Heat	0.25	Caribbean fruit fly	1.00	citrus	0.50
Commodity damage	0.55	sweetpotato weevil	0.05	mango	0.25
		anthracnose	0.20	papaya	0.09
		green mold	0.40	sweetpotato	0.08
		stem end rot	0.05	hog plum	0.08
Total SY:	**0.80**		**1.00**		**1.00**

Scientist: W. Gould

Treatment or aspect	SY	Pest	SY	Commodity	SY
Chemical	0.10	Caribbean fruit fly	0.80	carambola	0.20
Heat	0.35	papaya fruit fly	0.20	guava	0.20
Cold	0.35			mango	0.20
Irradiation	0.10			citrus	0.20
Inspection	0.10			papaya	0.20
Total SY:	**1.00**		**1.00**		**1.00**

Table II (cont'd)

ARS Manpower in Scientist Years (SY) Allocated to Quarantine Research

Miami (cont'd)

Scientist: G. Hallman

Treatment or aspect	SY	Pest	SY	Commodity	SY
Chemical	0.05	Caribbean fruit fly	1.00	carambola	0.25
Heat	0.20			guava	0.10
Cold	0.20			mango	0.25
Irradiation	0.05			citrus	0.30
Coating	0.50			misc. fruits	0.10
Total SY:	**1.00**		**1.00**		**1.00**

Scientist: J. Hansen

Treatment or aspect	SY	Pest	SY	Commodity	SY
Heat	0.60	sweetpotato weevil	0.70	sweetpotato	0.70
Commodity damage	0.20	banana moth	0.05	ornamental	0.10
Inspection	0.20	Caribbean fruit fly	0.20	citrus	0.20
		Thrips palmi	*0.05*		
Total SY:	**1.00**		**1.00**		**1.00**

Scientist: J. Sharp

Treatment or aspect	SY				
Irradiation	0.50	banana moth	0.25	mango	0.20
Microwave	0.50	sweetpotato weevil	0.25	citrus	0.30
		papaya fruit fly	0.10	papaya	0.10
		Caribbean fruit fly	0.40	sweetpotato	0.20
				ornamental	0.20
Total SY:	**1.00**		**1.00**		**1.00**
Location Total SY:	**6.80**		**7.00**		**7.00**

Table II (cont'd)

ARS Manpower in Scientist Years (SY) Allocated to Quarantine Research

Orlando, FL.

Scientist: R. McDonald

Treatment or aspect	SY	Pest	SY	Commodity	SY
Gibberellic acid	0.40	Caribbean fruit fly	0.50	citrus	0.50
Commodity damage	0.10				
Total SY:	**0.50**		**0.50**		**0.50**

Scientist: W. Miller

Treatment or aspect	SY	Pest	SY	Commodity	SY
Cold	0.40	NA	0.00	blueberries	0.10
Heat	0.25			carambola	0.25
Irradiation	0.50			citrus	0.50
Commodity damage	1.00			mango	0.15
Total SY:	**2.15**		**0.00**		**1.00**

Scientist: W. Schroeder

Treatment or aspect	SY	Pest	SY	Commodity	SY
Gibberellic acid	0.25	Caribbean fruit fly	1.00	citrus	1.00
Total SY:	**0.25**		**1.00**		**1.00**

Location Total SY:	**2.90**		**1.50**		**2.50**

Table II (cont'd)

ARS Manpower in Scientist Years (SY) Allocated to Quarantine Research

Weslaco, TX.

Scientist: R. Mangan

Treatment or aspect	SY	Pest	SY	Commodity	SY
Heat	0.50	Mexican fruit fly	0.50	citrus	0.60
		West Indian fruit fly	0.50	mango	0.20
				misc. fruits	0.20
Total SY:	**0.50**		**1.00**		**1.00**

Scientist: K. Shellie

Treatment or aspect	SY	Pest	SY	Commodity	SY
Heat	0.33	Mexican fruit fly	0.50	citrus	0.50
		West Indian fruit fly	0.50	mango	0.50
Total SY:	**0.33**		**1.00**		**1.00**

Scientist: S. Ingle

Treatment or aspect	SY	Pest	SY	Commodity	SY
Heat	1.00	Mexican fruit fly	0.50	citrus	0.60
		West Indian fruit fly	0.50	mango	0.20
				misc. fruits	0.20
Total SY:	**1.00**		**1.00**		**1.00**
Location Total SY:	**1.83**		**3.00**		**3.00**

Winter Haven, FL.

Scientist: P. Shaw

Treatment or aspect	SY	Pest	SY	Commodity	SY
Giberellic acid	0.10	Caribbean fruit fly	1.00	citrus	1.00
Total SY:	**0.10**		**1.00**		**1.00**
Location Total SY:	**0.10**		**1.00**		**1.00**

Table II (cont'd)

ARS Manpower in Scientist Years (SY) Allocated to Quarantine Research

Yakima, WA.

Scientist: H. Moffitt

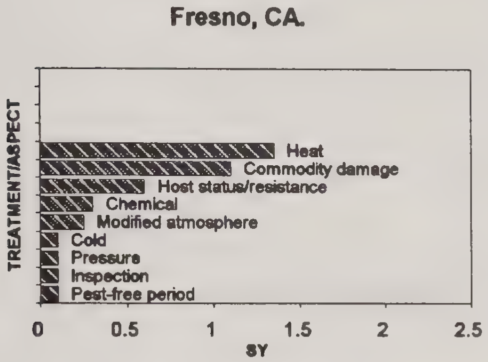
Treatment or aspect	SY	Pest	SY	Commodity	SY
Chemical	0.50	codling moth	0.45	apples	0.75
Heat	0.10	lesser appleworm	0.45	pears	0.10
Cold	0.10	western cherry fruit fly	0.10	cherries	0.15
Controlled atmosphere	0.10				
Systems	0.20				
Total SY:	**1.00**		**1.00**		**1.00**

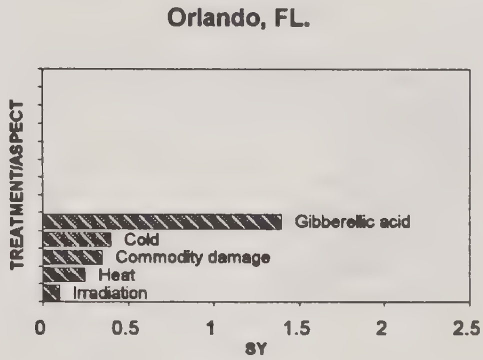
Scientist: L. Neven

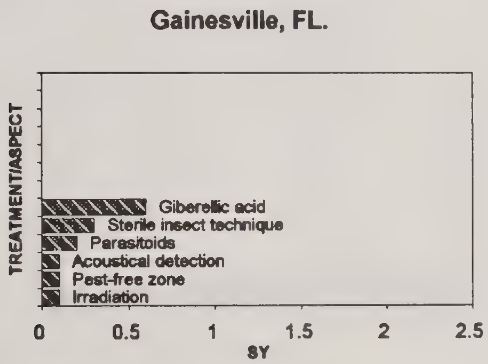
Treatment or aspect	SY				
Cold	1.00	codling moth	1.00	apples	0.60
				pears	0.15
				cherries	0.25
Total SY:	**1.00**		**1.00**		**1.00**
Location Total SY:	**2.00**		**2.00**		**2.00**

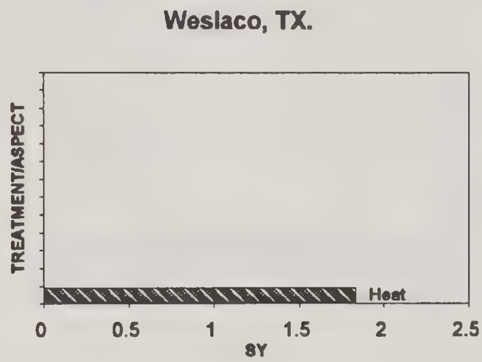
ARS Quarantine Research at Various Locations

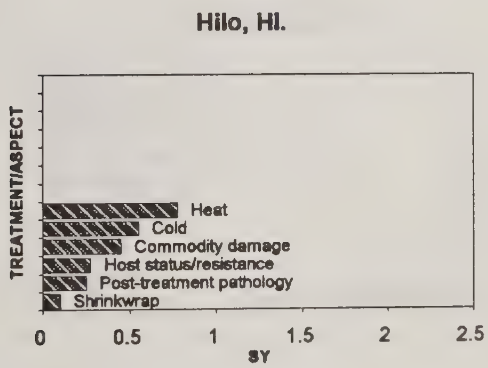
Scientist Year (SY) Allocation by Treatment FY92

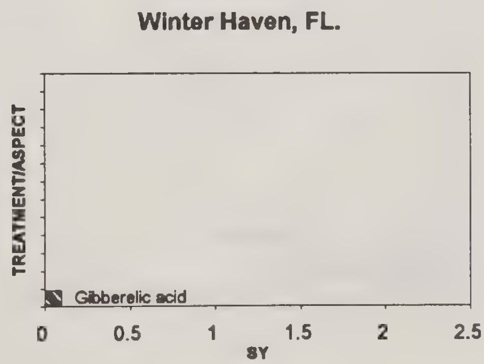


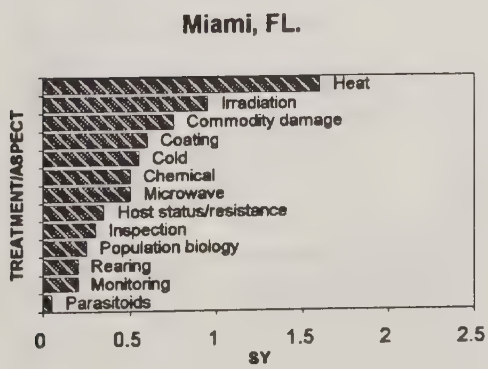


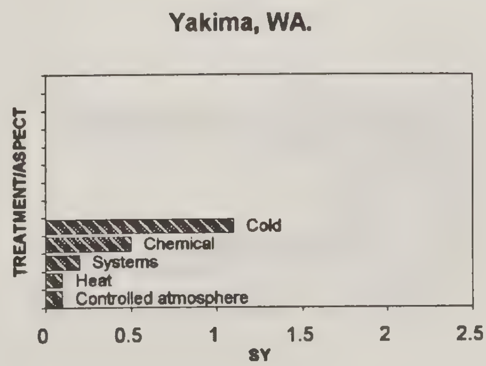






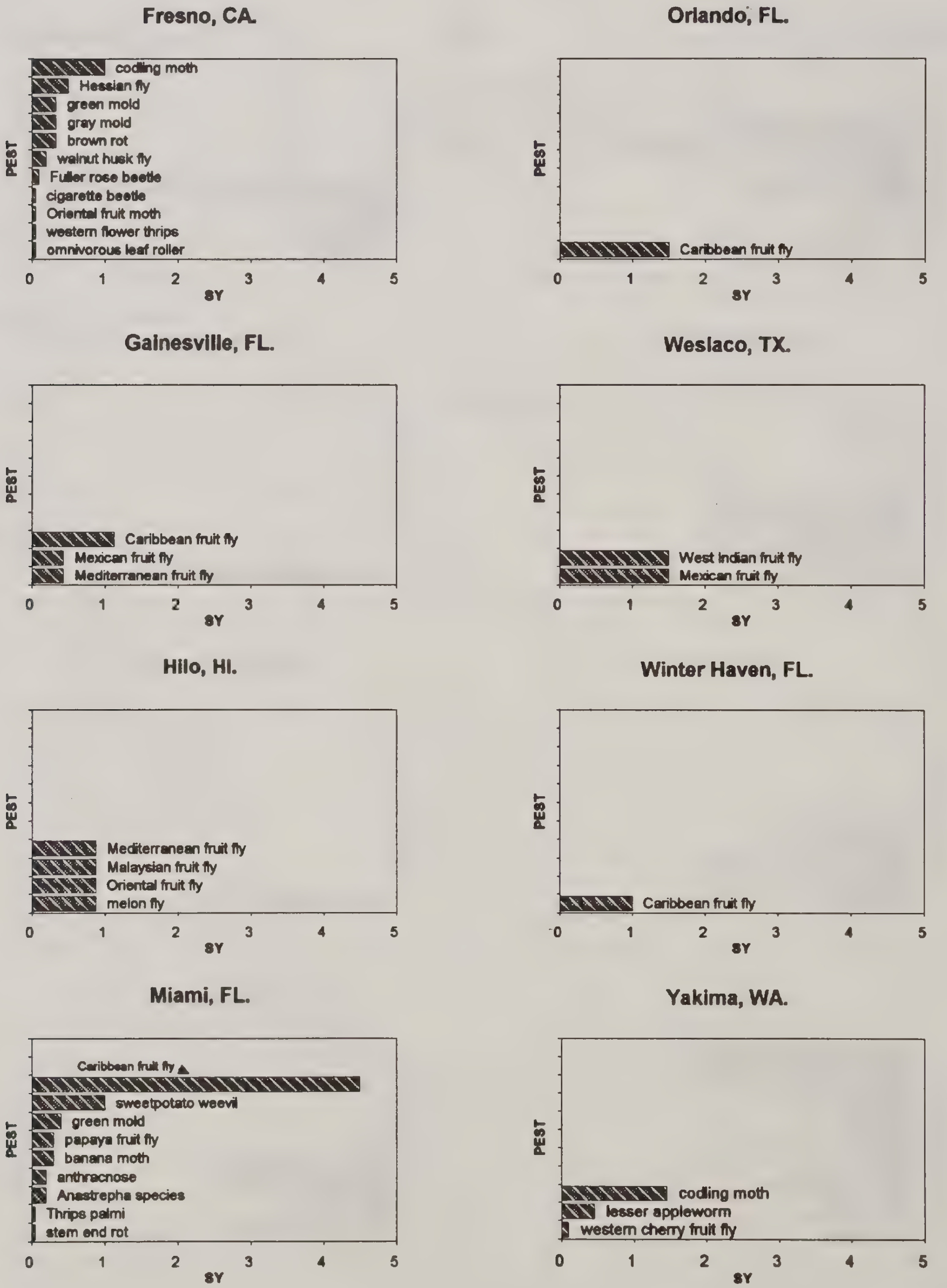






ARS Quarantine Research at Various Locations

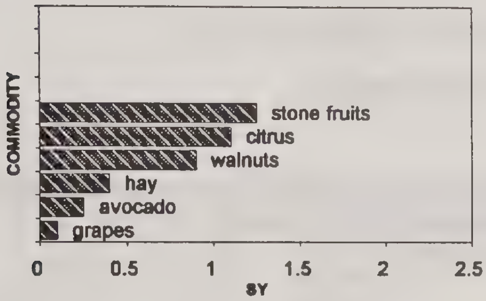
Scientist Year (SY) Allocation by Pest FY92



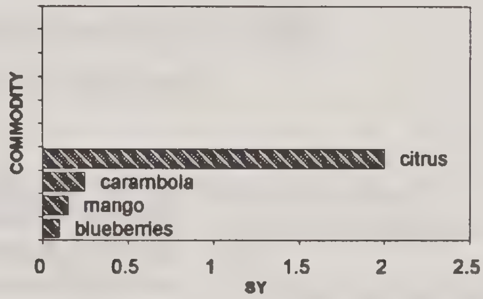
ARS Quarantine Research at Various Locations

Scientist Year (SY) Allocation by Commodity FY92

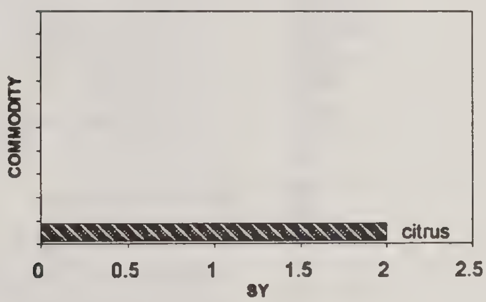
Fresno, CA.



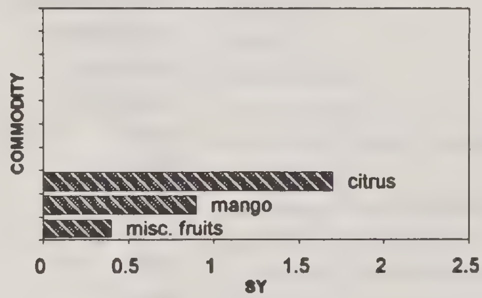
Orlando, FL.



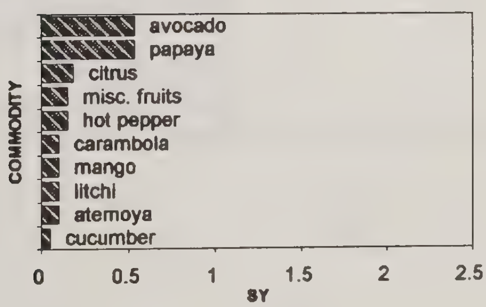
Gainesville, FL.



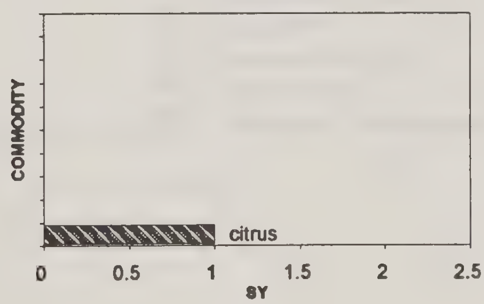
Weslaco, TX.



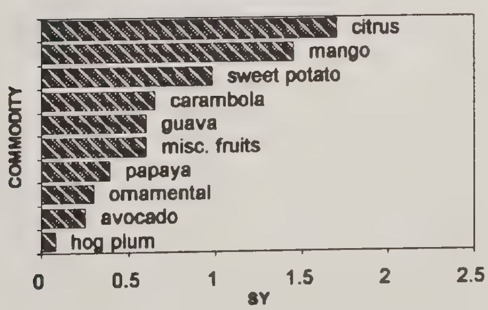
Hilo, HI.



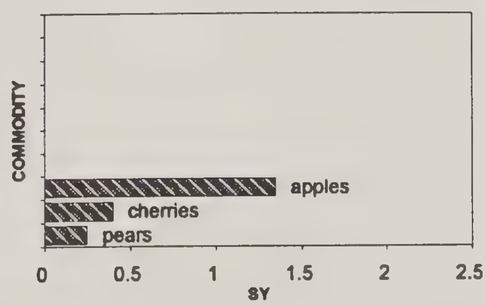
Winter Haven, FL.

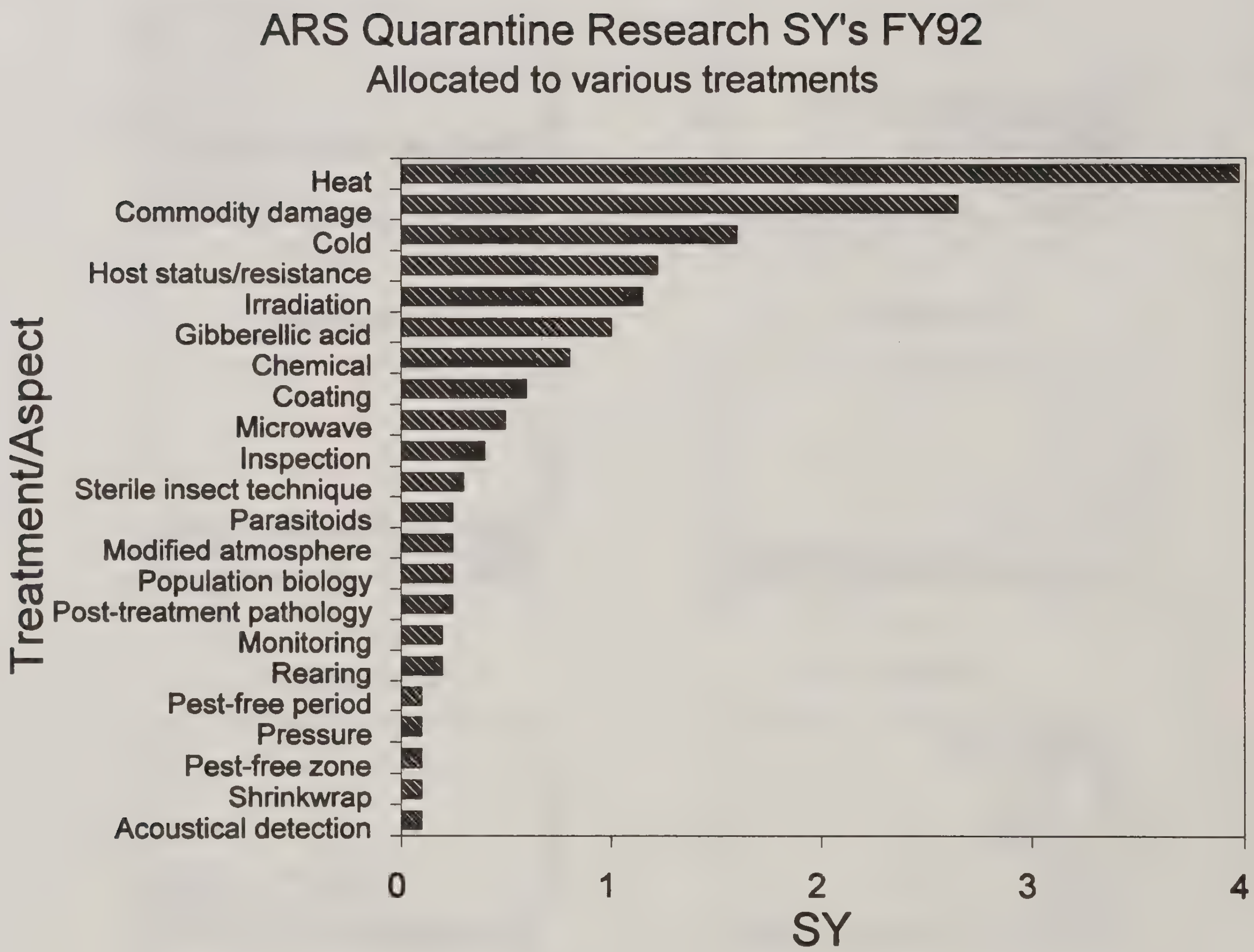


Miami, FL.

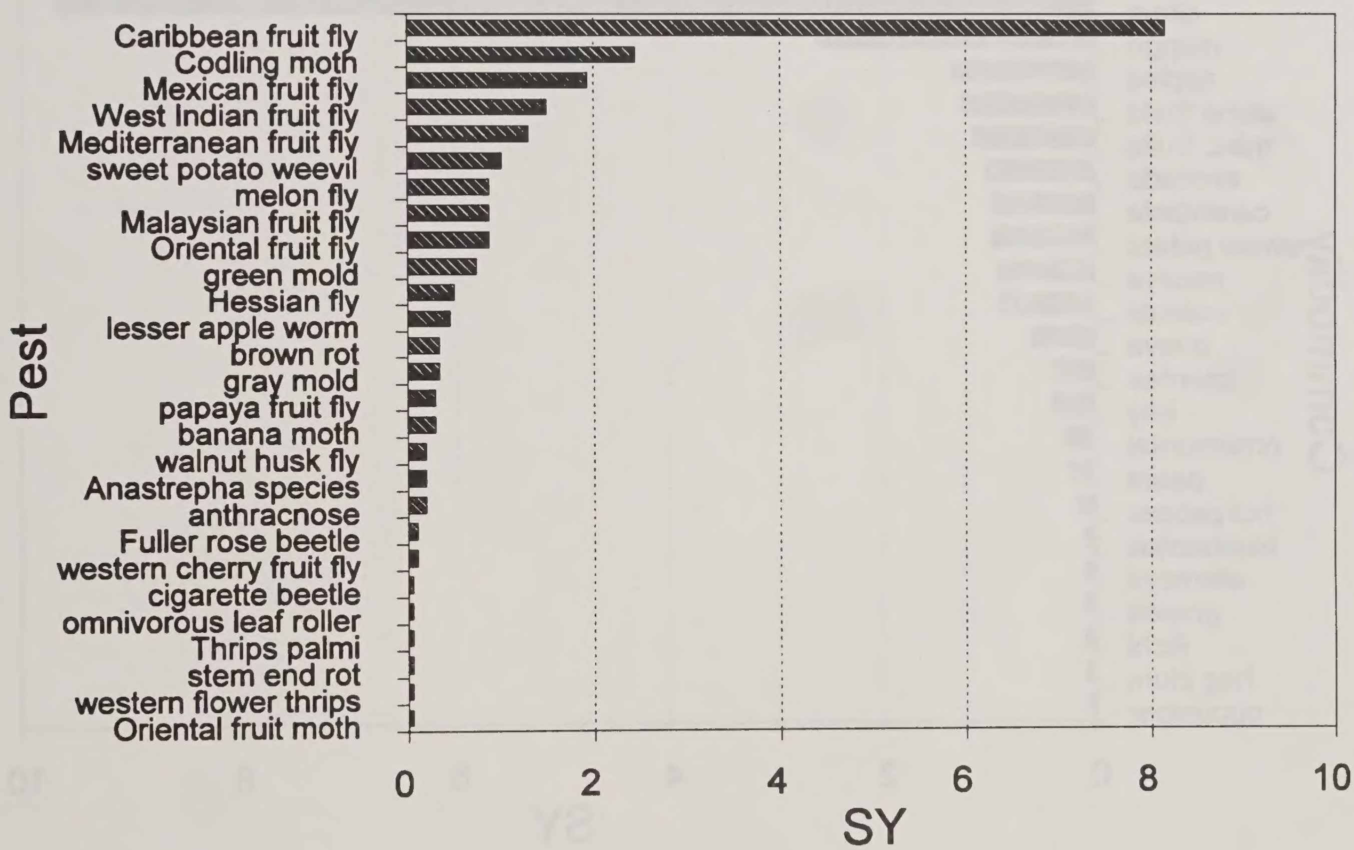


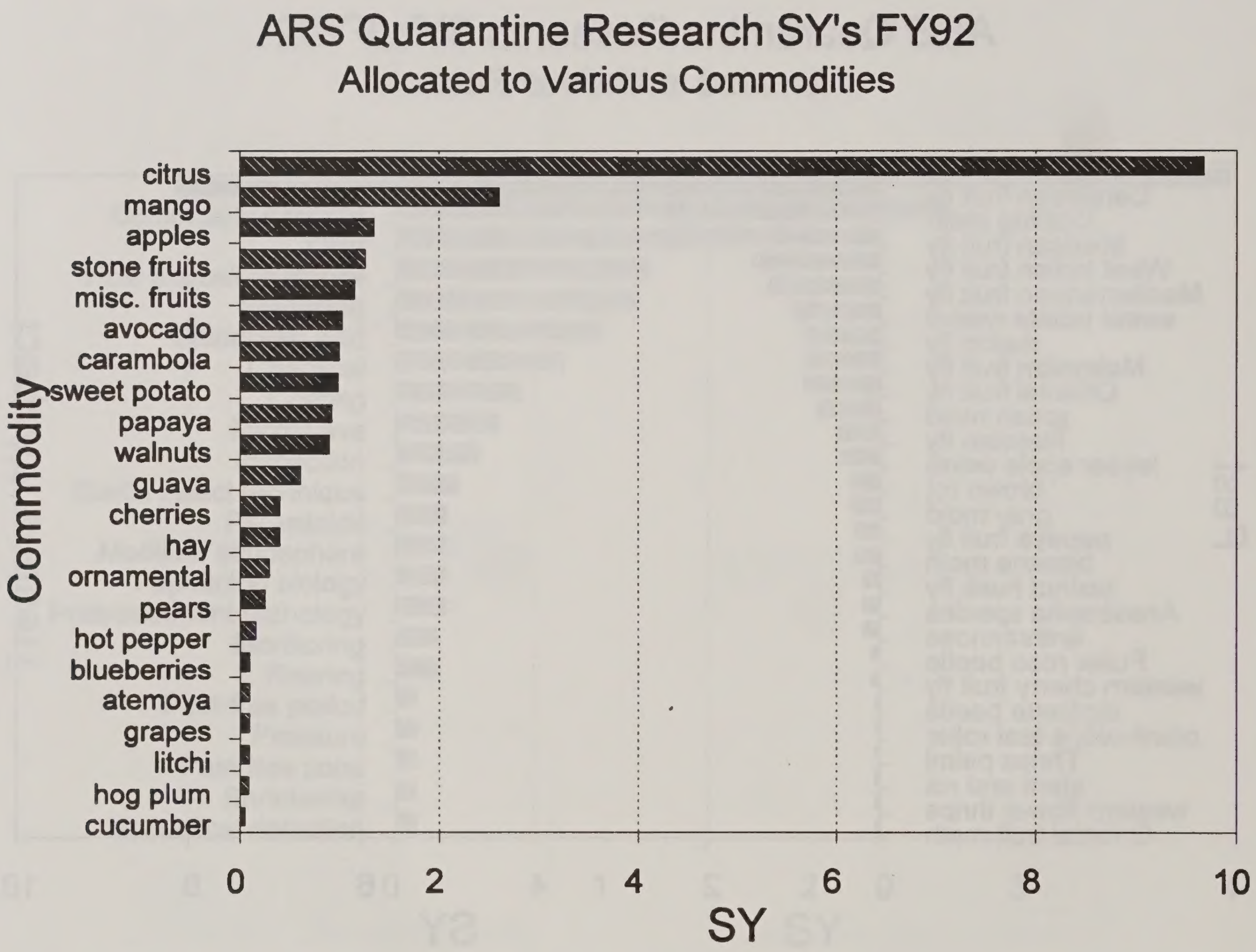
Yakima, WA.




ARS Quarantine Research SY's FY92
Allocated to various treatments
Treatment/Aspect
Heat
Commodity damage
Cold
Host status/resistance
Irradiation
Gibberellic acid
Chemical
Coating
Microwave
Inspection
Sterile insect technique
Parasitoids
Modified atmosphere
Population biology
Post-treatment pathology
Monitoring
Rearing
Pest-free period
Pressure
Pest-free zone
Shrinkwrap
Acoustical detection
0
1
2
3
4
SY

ARS Quarantine Research SY's FY92
Allocated to Various Pests





ARS Quarantine Research SY's FY92
Allocated to Various Commodities
citrus
mango
apples
stone fruits
misc. fruits
avocado
carambola
sweet potato
papaya
walnuts
guava
cherries
hay
ornamental
pears
hot pepper
blueberries
atemoya
grapes
litchi
hog plum
cucumber
Commodity
0
2
4
6
8
10
SY

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